Final Report

76-36

HumRRO
FR-ED(P)-76-36

HumRRO

Long-Term Retention of Flying Skills:

An Annotated Bibliography

by

Wallace W. Prophet

HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street • Alexandria, Virginia 22314

October 1976

Prepared for:

Assistant Chief of Staff, Studies and Analysis
Hq., United States Air Force
Washington, D.C. 20330

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: HumRRO-FR-ED(P)-76-36	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): LONG-TERM RETENTION OF FLYING SKILLS: AN ANNOTATED BIBLIOGRAPHY,	5. TYPE OF REPORT & PERIOD COVERED: Final Report. 1 May [illegible] – 15 Sept [illegible] 76
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Wallace W. Prophet	8. CONTRACT OR GRANT NUMBER(s): F44620-76-C-0106
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Human Resources Research Organization, 300 N. Washington Street, Alexandria, VA 22314	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: HEADQUARTERS USAF, Assistant Chief of Staff, Studies and Analysis, AF/SAA, Washington, D.C. 20332	12. REPORT DATE: October [illegible] 1976
	13. NUMBER OF PAGES: 138
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Retention	Memory	Retraining flight skills
Flying skills	Proficiency flying	Manpower management
Proficiency maintenance	Combat readiness training	Rated supplement flying
Skills maintenance	Continuation training	
Forgetting	Recurrency training	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In support of USAF Saber Wings II study, a survey of the state of behavioral science knowledge with reference to long-term retention of flying skills was conducted. Various literature sources were surveyed, as well as selected agencies and knowledgeable individuals. Abstracts or annotated references are presented for 120 references. Literature is grouped as: flight skill retention studies; non-flight skill retention studies; miscellaneous aviation studies; and literature reviews and references. Abstract length varies from

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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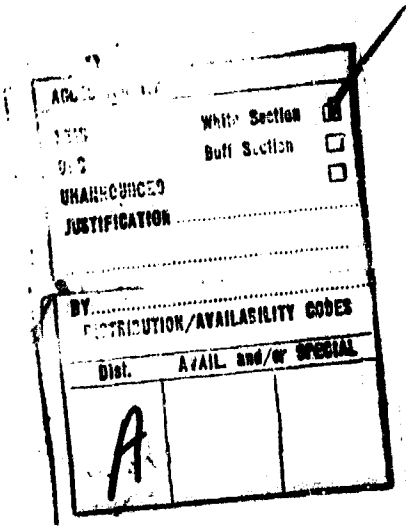
three pages to a single paragraph. An additional 80 references are given as reviewed, but not pertinent.



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FOREWORD

This report presents results of a survey of the behavioral science literature dealing with the subject of long-term retention of flight skills. The effort was performed for the Office of the Assistant Chief of Staff, Studies and Analysis, Hq., United States Air Force, in support of their studies of pilot proficiency and management of the rated force (SABER WINGS II). The literature survey results are presented here in the form of an annotated bibliography. Interpretive commentary relating that literature to USAF concerns is presented in a companion report, HumRRO FR-ED(P)-76-35.

Technical monitorship for this effort was provided by Dr. Robert N. Schwartz and Dr. Thomas C. Donohue of the Analysis and Evaluation Group, ACS/Studies and Analysis, Hq., USAF. Their assistance is gratefully acknowledged, as is that of numerous research colleagues in the US and in Europe. In addition, civilian and military flight training and management agencies have provided inputs, and a wide variety of library resources have provided assistance. Particular thanks are due the USAF Air University Library, Maxwell AFB, AL and many of its staff who provided most valuable assistance. Dr. Paul W. Caro, HumRRO, has provided technical input throughout the effort.

This project was performed under AFOSR Contract No. F44620-76-C-0106.

CONTENTS

I. INTRODUCTION

BACKGROUND

Aviation training represents one of the costliest manpower investments that the military services make. While determination of the cost of producing a combat-ready pilot for the United States Air Force is beyond the scope of this report, estimates in the range of $200,000-$300,000 are frequently given. In any event, the investment represented in the initial training of the more than 25,000 pilots presently in the Air Force is sizeable indeed. Thus, it is logical that the Air Force should be concerned about the best means to employ and maintain this resource. It is this concern, basically, that lies behind the study currently being conducted by the Air Force under the title of SABER WINGS II.

The career of the USAF pilot is one of constant training to maintain the high levels of skill required for operational missions. Such recurrent training is also costly and has come under increasing scrutiny by USAF, DoD, and the Congress. While it is clearly recognized by all concerned that the USAF must maintain a high state of combat readiness for a wide range of combat contingencies, the decreasing availability of fiscal and other resources to support the training required for that state of readiness has resulted in the direction of even greater attention to efforts to manage the pilot resource with maximum cost effectiveness.

The USAF pilot, in the normal course of his service career, will rotate through a series of job assignments after completing his undergraduate pilot training (UPT) and qualification in a combat aircraft through advanced training at one of the Combat Crew Training Schools (CCTS). After CCTS, he would normally be assigned to flying duty (cockpit assignment)

in an operational unit. After one or more such cockpit assignments, he will likely receive a non-flying assignment involving staff duty, advanced military or academic education, or other non-cockpit duties. It is the concern for the pilot's proficiency during these non-flying assignments that has led the Air Force to its SABER WINGS II study, to which this report is related.

It has long been recognized that pilot skills will deteriorate if not exercised regularly (as will most, if not all, human skills), and, consequently, the military services have required that most pilots engage in some amount of "proficiency flying" or "combat readiness training" during these non-flying assignments in order to retain their flying skills at an acceptable level. The amount of such proficiency flying has varied from time to time and service to service, but the required "annual minimums" have generally ranged from 80 to 120 hours. However, some such flying has been felt necessary in order to provide backup pilot manpower (i.e., the rated supplement) in a state of skill readiness sufficient for USAF to meet its immediate surge and longer range requirements in the event of hostilities. In addition, it has been felt that such flying was required to minimize retraining costs for personnel moving back into cockpit jobs from non-flying assignments.

Those who are familiar with the topic of proficiency flying are aware that it is a complex, even emotional, subject. We do not intend to explore the subject here, beyond noting that proficiency flying programs have been the subject of much discussion for many years, and many questions have been raised, such as:

How much time is required to maintain proficiency?

How much proficiency is required?

Are current programs effective?

What kind of aircraft should be used?

How can costs be minimized?

Is proficiency flying even required?

Should pilots receive flight pay if they do not engage in proficiency flying during non-flying assignments?

Will the pilot become "non-viable" in terms of his acceptability to the combat commander if he does not engage in proficiency programs?

Such questions have been asked over and over, and many forceful arguments have been advanced for and against proficiency flying. However, in recent years, these questions have taken on a new urgency because of continued cost escalation in the face of an increasingly strained defense budget situation. A most critical added dimension has been the Arab oil embargo of 1973 and the prospect that fuel resources to support flying programs in the manner of the past may simply not be available, regardless of fiscal resources. Thus, the alternative that some or all pilot personnel who are in non-flying assignments not be allowed to engage in any flying activities has become a very real one, one that the USAF must examine.

As has been noted, the topic of proficiency flying (or its possible elimination) is both important and emotional. Not only are there problems resulting from the possible conflicts among defense readiness requirements and increasing competition for available resources (not to mention the spector of possible loss of flight pay), there is the fact that <u>pilots like to fly</u>. The sheer enjoyment of flying is one of the main factors that has attracted most of them to the Air Force or the other flying services. Thus, the possible effects of various proficiency flying program alternatives, including that of no flying, on pilot morale, motivation, and career retainability are also a part of this picture of concern. As can be seen, the

problems of managing the pilot resource, the investment it represents, and the operational capabilities represented are exceedingly complex. In SABER WINGS II a systematic examination of these problems is being conducted, on the basis of which the USAF seeks to develop informed and effective policies for the future.

BEHAVIORAL SCIENCE RESEARCH

As one examines the various aspects of flying proficiency maintenance, it is apparent that one of its most fundamental dimensions is a behavioral one dealing with the conditions necessary to acquire, maintain, or reacquire complex skills. In addition, if one examines the history of proficiency flying programs, he sees that such programs (or opposition to them) have been based much more on rhetoric than on research. There are, in fact, few comprehensive research studies that have dealt with the subject of how best to maintain flying skills or with the rate or manner in which they degrade over time during periods of non-flying. Since an understanding of the learning and retention processes is so fundamental to USAF management of its rated supplement pilots, personnel in the Office of the Assistant Chief of Staff, Studies and Analysis, Hq., USAF, sought to have the literature dealing with long-term retention of piloting skills, particularly the behavioral science literature, systematically surveyed. The implications of that literature would be integrated with other inputs into their broad study of USAF problems in this general area. The work reported here, along with that in a companion report [1/], provides a basis for input into USAF deliberations.

Briefly stated, the objectives of the present effort were to survey

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1/ Prophet, W.W. Long-Term Retention of Flying Skills: A Review of the Literature. HumRRO FR-ED(P)-76-35, Human Resources Research Organization, Alexandria, VA, October 1976.

the literature on long-term retention of flying skills, to survey selected knowledgeable researchers and agencies who might be working in the content area, to summarize the literature in the form of an annotated bibliography, and to provide an interpretive report presenting major implications of that literature for future Air Force actions. The present report is the annotated bibliography.

METHOD

In carrying out the literature survey, conventional methods were followed. The principal document sources utilized were the various HumRRO office libraries, particularly that of the HumRRO Pensacola Office with its more than 25,000 items, mostly in the field of aviation psychology. Other document sources included the USAF Air University Library at Maxwell AFB, AL, the Library of the Aviation Research Laboratory at the University of Illinois, the University of West Florida Library, the Defense Documentation Center (DDC), and the National Technical Information Service (NTIS). Professional colleagues, both military and civilian, in this country and in Europe, provided documents and suggestions for other sources, as well as general observations about the retention problem. The FAA, NASA, and the airline industry also provided inputs.

In conducting the literature search, several basic source documents were especially useful. A wide-range computer bibliographic search dealing with flying skill acquisition, forgetting, and retention was requested from DDC. The print-out of titles and abstracts totaled about 1,400 items. Of course, the bulk of these were not pertinent, but many were. DDC also provided a print-out of Work Unit Summaries of current research dealing with flying skills. In addition, searches were made of Psychological Abstracts and Dissertation Abstracts. Other particularly helpful starting

points were previous reviews of the literature pertinent to flying skill retention contained in reports by Smode, Hall, and Meyer (1966), Wright (1969), Gardlin and Sitterley (1972), and Smith and Matheny (1976).[1/] As titles were developed from these and other sources, abstracts of the documents, or the documents themselves, were examined to make a preliminary determination of their pertinence to the present effort. If deemed pertinent, an attempt was made to secure the item from HumRRO or other library or document sources for first-hand examination and review. While a few documents that surfaced by this procedure could not be secured (e.g., an organization's internal research memorandum or note, no longer retrievable), the great preponderance of items sought was secured. Eventually, a file of more than 200 documents was assembled for review. Some of these are not included here because, upon inspection, they proved to be irrelevant to this report.

While no claim is made here that all the significant literature directly pertinent to the subject of long-term retention of flying skills was discovered, we feel that most of the significant literature is represented. Undoubtedly, more time and greater resources for the search might have yielded additional items of significance, but major change would seen unlikely.

A word is in order concerning what was and was not included in this search. The search was generally directed toward studies dealing with flying skills per se, or studies dealing with perceptual-motor skills reasonably pertinent to flying or complex performance. No attempt was made to cover systematically the general learning/forgetting academic literature

1/ The reader is referred to the bibliographic listing in Section II of this report for full citations of these documents.

on the grounds that (1) most of it is of peripheral concern, at best, to current USAF problems (it is overwhelmingly concerned with verbal learning), and (2) time and resources did not permit. However, certain items from this area were included.

As the reader examines the literature covered in this review, he cannot help but be impressed by its relative paucity, considering the importance of the topic. At least three reasons can be cited for this lack. First, the conduct of flight training research is quite costly, particularly when high skill levels for complex military aircraft are involved. Second, achieving appropriate and rigorous experimental control of the activities of test subjects during a no-practice retention interval is virtually impossible for the subject populations and time intervals (i.e., 1-3 years) of concern. And, third is the fact that the requirement for such research apparently has not been brought to the attention of defense budget managers and decision makers in a manner sufficiently forceful that the research would receive the long-term support necessary for its effective conduct. The recent fiscal and fuel crises have changed this situation, and the need for such information is more clearly recognized.

ORGANIZATION OF THE REPORT

There are seven sections of this report, including the present introductory section. Section II provides basic bibliographic reference citations, arranged alphabetically by author or originating agency, for the items for which abstracts or annotations, in varying degrees of detail, are provided in Sections III-VI. Finally, Section VII contains a bibliographic listing of certain items that were reviewed in some detail, but are not abstracted here because they are of no strong pertinence to the subject of concern.

Section II contains a page indexing indicating where in Sections III-VI the annotation for each of the items can be found. In some instances, several citations may be covered by a single abstract or annotation. This is done when the same research study (or portions thereof) may have been published in several formats (e.g., as a technical report and in a professional journal), or when a series of closely related research studies may have resulted in several publications. Three formats, generally corresponding to level of detail, are used in the annotations, as follows:

Level A - A four paragraph format is used. The first paragraph provides a brief description of the study or effort. The second paragraph summarizes major results, while the third summarizes major conclusions. The fourth paragraph is a comment by the present author, sometimes evaluative, relating the effort to the retention problem of concern here.

Level B - A two paragraph format is used, with the first paragraph being a summary of the effort in terms of problem, method, and results. The second is a comment similar in nature to that described for Level A.

Level C - A single paragraph is used, often only a few sentences, to comment on selected aspects of the effort reported.

In general, the A format is used only for efforts felt to be of relatively major importance to the present review. These items also are in the nature of experiments or studies in which there are data gathered dealing with effects of experimental variables or conditions. The B format is used for items of lesser import in the present context or, in some cases,

for items that might be of major importance in the present context, but which were not of the nature of an experiment, for example, a review of literature. The items presented in the C format are items judged to be of relatively minor importance in the present context.

Sections III-VI contain groupings of the annotated references, as follows:

Section III contains abstracts of those items that are direct studies of the retention of flying skills or flight related skills such as a radar intercept task skill. Some deal with whole-task studies, while others deal with part-tasks, and both aircraft and simulator studies are included.

Section IV contains retention studies dealing with more general motor skills or procedural tasks. These studies are of interest, but require somewhat greater extrapolation for application to the flight skill retention area than do the items in Section III.

Section V includes a variety of non-retention aviation studies that deal with the acquisition of flying skills (as opposed to their retention), aircraft accident data, the nature of the pilot task, transfer of training, and similar areas of interest. These are not retention studies, though they are of relevance to the subject.

Section VI contains references to other literature reviews or textbooks.

Only one item (the Smith and Matheny review) appears in more than one section. It is in both Section III, because it contains data not elsewhere available, and in Section VI, because it is basically a literature review.

In listing the items in Sections III-VI, the Level A and Level B items are intermixed, appearing generally in the alphabetical order in which they are listed in Section II, while the Level C items appear only after the A and B listings. In order to ease the work of manuscript typing, each A and B item begins on a new page even though this adds a little bulk to the document.

II. BIBLIOGRAPHY INDEX

This section gives the basic bibliographic citation for all items for which abstracts or annotated information is presented in Sections III-VI of this report. Items are arranged alphabetically by author (or agency if no individual author is given) and are numbered serially. Also shown for each item is the format in which it is abstracted, i.e., Levels A, B, or C. Level A contains four paragraphs and, generally, more detail than is given in the other two formats. Level B contains two paragraphs and is more detailed than Level C, which contains only a single paragraph.

For each item listed, a page location is given to aid in locating the abstract in Sections III, IV, V, or VI. For example, an item that shows Level A, page III-12, is a four paragraph format abstract that can be found on page 12 of Section III. Similarly, an item listed as Level C, page V-6, is a single paragraph abstract located on page 6 of Section V. As has already been noted, each reference item appears in only one section with the exception of the Smith and Matheny report that appears both in Section III and Section VI.

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III. FLIGHT SKILL RETENTION STUDIES

This section contains those studies that deal directly with the subject of retention of flying skills. Some are concerned with global evaluations of whole-tasks or overall flight skills, while others are concerned with part-tasks or more restricted segments of flight skills. Both aircraft and simulator studies are included. In the case of some simulator studies, the flight skill task studied may be a synthetic task that deals with a skill that is sufficiently flight-like that the study is included in this section rather than in the section dealing with more general, non-flight motor skills. In some instances, a study might well have been included in Section IV rather than Section III, but in any event, both Section III and Section IV are of primary interest in the present context because they deal with retention studies.

REFERENCES INCLUDED IN SECTION III

Formats A & B

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3. Adams, J.A., Hufford, L.E., and Dunlop, J.M. Part- Versus Whole-Task Learning of a Flight Maneuver. NAVTRADEVCEN 297-1, U. S. Naval Training Device Center, Port Washington, NY, 1960.

49. Hufford, L.E., and Adams, J.A. The Contribution of Part-Task Training to the Relearning of a Flight Maneuver. NAVTRADEVCEN 297-2, U. S. Naval Training Device Center, Port Washington, NY, 1961.

1. Description

The purpose of these two companion studies was to investigate the contribution of part-task training to the learning and relearning (after a period of 10 months) of a fairly complex flight maneuver (bomb-toss) performed in an operational flight trainer for the SNJ aircraft. The study was concerned with the use of part-task trainers in the teaching of complex time-shared tasks. Experimental group Ss (N=16) learned the procedural and flight-control components separately as part-tasks, while Control Ss (N=14) learned on a whole-task basis in the SNJOFT. Ten months later, 10 Ss from each group participated in a retention-relearning study.

2. Results

a. There was little difference in the relative effectiveness of whole- and part-task training in the original learning, except for a decrement in performance of procedures by the experimental group on their first whole-task trial.

b. Forgetting of procedures was virtually complete over the 10-month interval, dropping from 95% correct on the last original learning trial to only 5% correct on the first retention trial.

c. Retraining of procedural skills on a part-task basis did not restore procedures performance to original levels when procedures were required to be performed in the whole-task (time sharing) situation.

d. Control of bank angle showed a statistically significant loss in proficiency over the 10-month interval; however, the mean increase of less than two degrees was not considered to have practical operational significance for flight training.

e. Mean vertical speed error increased from about 150 ft/min on the last original learning trial to about 500 ft/min on the first retention trial. For the experimental group with procedural retraining before the whole-task trials, original proficiency was regained by the second three-minute trial. For the group not receiving this training, performance was not regained until the fifth trial in retraining. This substantial loss in vertical speed control differs from other studies that have shown no substantial loss in control of other continuous parameters. The substantial

lag in this parameter, or highly procedural components in it in the bomb-toss maneuver used, were hypothesized as the basis for this loss.

3. Conclusions

a. Substantial losses in procedural skills occurred over the 10-month interval. Bank control remained good over the interval, but vertical speed error increased markedly.

b. Cockpit procedures training, although reducing retraining time, could not completely restore lost proficiency in procedures. Some additional whole-task practice was required to fully restore whole-task performance.

c. Time-sharing is a variable in recall and relearning, just as it is in original learning.

d. A simulator that allows whole-task practice is the best device for the retraining of task skills that involve time sharing, but quite simple devices can still be used to considerable advantage.

4. Comments

These were well-designed studies with data gathered under well-controlled conditions. The results are generally consonant with those of a number of other investigations. The studies suffer in terms of the somewhat restricted nature of the single maneuver involved and in terms of the rather limited sampling of flight control parameters for study. Nevertheless, while they clearly show the considerable effects of time on the retention of procedural skills, they also show that those skills can be easily relearned.

6. American Airlines, Inc. Requalification Take-off and Landing Study. American Airlines Flight Training Academy, Fort Worth, TX, February 1976.

1. Description

The objective of this study was to determine whether a modern digital flight simulator, with rigid model color visual system, could be used to provide training in take-off and landing sufficient to meet proficiency requirements of FAR 121.439.[1/] Take-off and landing performance in the aircraft of 80 simulator trained subjects was compared with that of 80 control subjects who were trained under FAR 121.439. A variety of aircraft types were examined (B-747, DC-10, B-707, and B-727), and all simulator program subjects were (a) current in another type airline aircraft than that to which being trained and (b) had made at least 3 take-offs and landings in the preceding 24 months in the type aircraft for which being trained (i.e., requalified). Training was to proficiency, and the first two landings in operations subsequent to the training served as the transfer trials.

2. Results

a. Time to proficiency in the simulator varied from 35 minutes to 2 hours, with the mean time being 1.1 hours.

b. Mean time to proficiency in the simulator was 1.17 hours for Ss who were 3-6 months non-current; 1.05 hours for those 6-12 months non-current; and 1.08 hours for those 12-24 months non-current.

c. Take-off and landing grades (5 point scale) in the aircraft were as follows for the Control and Simulator Groups:

Months Non-Currency	Control		Simulator	
	T-Off	Ldg.	T-Off	Ldg.
3- 6	3.27	3.37	3.69	4.01
6-12	3.46	3.44	3.27	3.33
12-24	3.07	3.29	3.31	3.16
>24	3.13	3.38	-	-
Overall Average	3.33	3.40	3.49	3.60

3. Conclusions

a. Training in the simulator was equal to or better than that provided by the accomplishment of 3 landings in the airplane (FAR 121.438).

b. Study personnel felt that the pilot should have a minimum amount of prior experience in the aircraft type (typically recommended 100 hours) as a prerequisite to substituting the simulator training for aircraft experience required under FAR 121.439.

1/ This section of the Federal Air Regulations requires that to function as Pilot in Command or Second in Command on an airliner, the pilot must have made at least three take-offs and three landings within the preceding 90 days in the type aircraft in which he is to serve.

4. Comment

This effort was not a retention study in the sense of examining performance after a period of no flying activity; subjects were current in other fleet aircraft and, presumably, were regularly engaging in flying operations as pilots. The results suggest no relationship between the length of the non-currency period for the training aircraft and performance in that aircraft after retraining, but this observation must be examined in light of the pilots' flight currency in other aircraft. The display of the data in the report makes detailed interpretation difficult, because no significance tests are used and the size of certain subgroups (e.g., by non-currency periods) is not given. Also, while it is felt by the authors that the new training (i.e., with the simulator) is equal to that under FAR 121.439, it would have been desirable to compare their performance with another control group who received no training at all. In the background section of the report, a graphical display is given of average simulator and aircraft hours to transition Captains, for several aircraft and for several years. Because of their interest, the data (estimated from the graph) are given here.

	747		707		727		DC-10	
Year	Sim	AC	Sim	AC	Sim	AC	Sim	AC
1966	-	-	-	18.0	-	21.0	-	-
1967	-	-	27.0	12.5	28.0	12.5	-	-
1968	-	-	24.0	10.2	27.5	8.1	-	-
1969	-	-	23.0	7.5	27.8	8.0	-	-
1970	28.0	5.5	22.0	5.6	24.8	6.0	-	-
1971	27.0	5.0	19.5	3.5	23.0	3.5	23.4	3.5
1972	26.5	3.6	22.0	2.9	23.5	3.1	23.0	2.7
1973	21.5	3.4	20.2	2.0	22.7	2.9	24.9	2.2
1974	19.9	2.0	19.0	1.2	19.5	1.2	24.0	1.6
1975	19.5	1.8	19.5	1.3	19.5	1.0	24.2	1.6

In spite of its shortcomings from the research point of view, this report provides significant data concerning the use of flight simulators to requalify pilots in a difficult skill area, that of take-off and landing. It suggests that current visual simulation technology is sufficiently advanced that significant portions, if not all, of the major USAF retraining requirements, including at least some visual reference maneuvers, can be trained in the simulator. This is an hypothesis that is worthy of research examination by the USAF.

7. Ammons, R.B., Farr, R.P., Bloch, E., Neumann, E., Dey, M., Marion, R., and Ammons, C.H. "Long-Term Retention of Perceptual Motor Skills." J. Exper. Psychol., 1958, 55, 318-328.

1. Summary

Retention of a procedural skill and a compensatory pursuit skill over time intervals ranging up to two years was examined in a laboratory setting. The independent variables were amount of training and retention interval. Results showed time to execute procedures was about twice as large after one month as at the end of training and increased by a factor of 3-4 by the end of two years. Time-on-target scores on the pursuit task held up fairly well for up to six months for those Ss who received more training, but for those with less original training, degradation was noticeable at six months. Overall, however, it was found that, on the bases of mean time taken per trial or percentage time on target per trial, absolute loss in level of proficiency was apparently not affected by amount of training and was greater the longer the no-practice interval.

2. Comment

This is one of the most elaborate and well-controlled studies of long-term retention in the literature. It involved almost 1,000 subjects and examined fairly long retention intervals. The tasks studies bear some general relevance to pilot control tasks, but their level of complexity is far from that which would allow unqualified generalization to mission oriented USAF pilot control tasks. The data are compatible, in general terms, with those of studies more directly relevant to piloting skills, however, and there is no reason here to conclude that simple skills and complex skills are fundamentally different in terms of their retention over time. While not directly analyzed, the data do support the thesis that procedural skills show greater degradation over time than do tracking skills.

8. Armstrong, M.B., Bleymaier, J.S., Hinkel, J.F., Levins, R., and Sheppard, R.R. Flying Skill Retention and Proficiency Flying. Research Report No. 0095-75, Air Command and Staff College, Air University, Maxwell AFB, AL, May 1975.

1. Summary

This document is a broad examination of USAF proficiency flying programs in view of existing literature on retention of flying skills. The effort was conducted in connection with the authors' studies at the Air University and at Auburn University. An extensive review of the background, history, and current status of USAF proficiency flying is given, along with a review of selected research literature on general skill retention and literature on flight skill retention.

The authors touch on a wide variety of bibliographic sources in their report. Some 41 items, varying from newspaper articles to research reports to AF regulations, are cited in the bibliography. Detailed summaries of 12 of these items, studies of general skill retention, are given in an appendix. Another appendix cites 30 references as being "irrelevant" to their study, in spite of titles that sound relevant.

While this document contains a great deal of information of considerable interest, the most interesting part is a chapter detailing certain analyses of data concerning the retraining of USAF POWs returned from Vietnam. They note that data were available on the retraining of 150 former POWs to a presumably equal proficiency level in T-37, T-38, and T-39 aircraft. Armstrong et al confined their analysis to the retraining records of 96 pilots, all retrained in the T-38. Their analysis examines retraining time as a function of: (1) hours of fighter time; (2) hours total flying time; (3) months rated experience prior to break in flying (i.e., capture as POW); and (4) months in non-flying status (i.e., time from capture to beginning of T-38 retraining). Their analysis and data base are somewhat more extensive than that reported by Smith and Matheny,[1/] the only other published source found on USAF POW retraining during the present review. Raw data files for the 96 pilots are presented in an appendix by Armstrong et al, along with regression analyses.

The 96 former POWs varied from 50 to 6,322 hours of fighter time (M=1,159); from 304 to 7,747 hours total time (M=2,100); months rated prior to capture from 9 to 286 (M=66). Retraining time, under the highly individualized, on-demand retraining program, ranged from 12 to 95 hours (M=45).

Results showed small negative correlations between hours of retraining time and all variables except length of non-flying interval. Of the negative correlations, only that with total fighter time was statistically significant ($r = -.237$; $p < .05$). The correlation of non-flying episode and retraining hours was also statistically significant ($r = +.334$; $p < .001$).

1/ Smith, J.F., and Matheny, W.G. Continuation Versus Recurrent Pilot Training. AFHRL-TR-76-4, Air Force Human Resources Laboratory, Brooks AFB, TX, May 1976.

From the diverse sources consulted and the POW data, the authors conclude that a proficiency flying program is required for the rated supplement to meet readiness requirements. They provide suggested characteristics of such a program, and a model or program for determining who should go into the rated supplement and, further, who should be identified as surge, drawdown, and controlled rotation.

2. Comment

This a very ambitious paper. While the task the authors set themselves was a large one, they gave the subject a good examination. The leap from data to conclusions to recommendations was extensive, and one might debate the validity thereof. The principal value of this document is not its review of the research literature, but the good overview of the entire subject of USAF proficiency flying it provides and the exposition of the POW retraining data. Some of the correlational analyses are not appropriate due to discontinuities in the data, and the authors recognize that any relationships found in these data may be significantly colored by the "overriding psychological factors of the many readjustments and other pressing interests of the POWs during the retraining period." They then use this rationalization, seemingly, to support interpretations that are more in line with their expectations. In spite of this, Armstrong et al have provided a rather significant document on the topic of proficiency flying.

24. Caines, K.L.D., and Danoff, M.N. Proficiency Flying Program Study. PRC-R-952, Planning Research Corporation, Los Angeles, CA, March 1967.

1. Description

This study, conducted for OASD(SA), had two objectives: (1) to determine the proficiency level of pilots who had been taking part in proficiency flying programs while in administrative assignments; and (2) to develop cost-effective training programs and equipment for alternative proficiency flying programs. The method involved examination of the training records of 178 pilots: 84 USAF pilots who had gone through F-4C CCTS training; 17 USN aviators who had gone through A-4E CRAW training; and 78 USAF pilots who had gone through C-130E CCTS training. The basic unit of analysis was number of deficiencies (by mission or flight segment or element) per 100 flights. Pilot proficiency degradation areas attributable to proficiency flying were identified by comparing records of those who had been on proficiency flying assignments (varying from 0.5 to 5.0 years) just prior to CCTS or CRAW with records of those who went to CCTS or CRAW from a cockpit assignment that involved flying duty. Most comparisons were based on CCTS training involving an aircraft type different from that flown before CCTS or proficiency flying.

2. Results

(a) Pilots who had been in proficiency flying assignments exhibited significantly more deficiencies per 100 training flights than did those who had not been in proficiency assignments.

(b) Areas of significant deficiency included takeoff, general airwork, navigation, tactical formation, bombing, tactics, and normal landing.

(c) Tasks involving high information volume and rate with simultaneous motor requirements were areas of deficiency.

(d) Pilots who had been in proficiency flying for more than 2 years had significantly more deficiencies than those with less than 2 years.

3. Conclusions

(a) Proficiency pilots are less proficient than pilots who have been in flying assignments.

(b) Proficiency flying programs need to be changed to remedy deficiencies and to upgrade readiness.

4. Comment

This study was undertaken with an expectation that pilots who had been in proficiency flying assignments would show performance deficiencies in CCTS or CRAW training. That expectation was fulfilled. The data leave much to be desired. For example, the bulk of the comparisons made involve

pilots who had previously flown an aircraft type different from that used in CCTS training. Also, C-130 data were for the final checkride flight only, whereas F-4 and A-4 data were for training flights only. The data displays do not allow the reader to examine in detail the rationale for conclusions reached. The procedure used assumes that all pilot groups were at equivalent proficiency levels at the end of their last cockpit flying assignment and/or CCTS training. While the basic conclusions of the study may be valid, their underpinning, in terms of data displayed, could be stronger.

26. Cotterman, T.E. and Wood, M.E. Retention of Simulated Lunar Landing Mission Skill: A Test of Pilot Reliability. Aerospace Medical Research Laboratories, Technical Report No. AMRL-TDR-66-222, Wright-Patterson AFB, OH, April 1967.

1. Description

This study was part of NASA's program of research on long-term skill retention. Specifically, the effects of no-practice periods of up to 3 months on the retention of lunar landing mission skills were examined. Four three-man crews served as subjects. All were graduates of the Aerospace Research Pilots School. Following five weeks of premission training on various aspects of the mission, each crew performed the full lunar landing mission requiring 169 hours. Full size simulations of the Apollo Command Module and the Lunar Excursion Module were used. One crew was tested for retention after 4 weeks; another after 8 weeks; another after 9 weeks; and another after 13 weeks. Retention trials were done in fast time, i.e., they took only 13 hours due to elimination of the long translunar and trans-earth coast periods. A wide variety of performance measures was used in this investigation, with most lending themselves to summarization as mission/phase probability of success.

2. Results

a. The four crews achieved variable levels of skill in their original training.

b. All crews exhibited decrements in performance after the no-practice interval.

c. No difference in degree of decrement was found between the 8-weeks and 13-weeks retention interval.

d. Crewmembers tested second or third seemed to benefit from the opportunity of viewing (and participating in) the first crewmember's testing.

3. Conclusions

a. " . . . it seems fair to conclude from the present study that without special design attention operator reliabilities in critical tasks performed after 8 weeks or more without prior direct familiarization are likely to be unacceptable."

b. Pilot performance reliability can be made sufficiently high through appropriate training to permit successful execution of extended spaceflight missions of the type studied here.

4. Comment

This is the most elaborate of all the retention studies examined. The task was exceedingly complex and lengthy, and the equipment, instrumentation, and data used were also the most complex. However, there are a number

of factors that make generalization of these results to the aircraft piloting skills retention problem somewhat difficult. First, only four crews were involved, one to each retention interval. Second, the summary reliability data are difficult to translate into task details. The fact that the various crews apparently were not trained to the same level of original skill makes it difficult to assess the effects of retention interval since there was only one crew per interval. And, finally, there is no way to assess the effects of the various activities of these military test pilots that were interpolated between the original training and the retention test. Nevertheless, this is an important, pioneering effort that provided highly valuable input to the successful spaceflight program.

30. Fleishman, E.A., and Parker, J.F., Jr. "Factors in the Retention and Relearning of Perceptual-Motor Skill." J. Exper. Psychol., 1962, 64, 215-226.

77. Also published as: Parker, J.F. Jr., and Fleishman, E.A. The Retention of a Continuous Control Perceptual-Motor Skill. Technical Report PRA 60-37, Office of Naval Research, Washington, DC, July 1960.

1. Description

This study investigated the effects of retention interval, amount and type of initial training, and type of retraining on retention and relearning. Two groups of subjects were given extended training on a highly complex tracking task--a simulated radar intercept mission. Practice extended over 17 sessions distributed over 6 weeks. The groups differed only in the amount of verbal guidance provided in initial training. Within each group, subgroups of subjects matched for final proficiency were retested following various no-practice intervals of up to 24 months. These retention samples were further divided into two subgroups, each of which was given four additional retraining sessions. In one group, this relearning practice was massed in one day, and for the other group, it was distributed over four days. One week following the retraining all subjects were retested as a means of evaluating the persistence of the effects of these two relearning schedules.

2. Results

a. The retention of proficiency in a complex, continuous control, perceptual-motor skill is extremely high, even for no-practice intervals up to 24 months.

b. Variations in retention interval from 1 to 14 months are shown to be unrelated to retention performance, even during the first 1 minute of relearning. The function has zero slope until the loss in performance shown by the 24-month retention group.

c. The most important factor in retention is the level of proficiency achieved by the subjects during initial learning. This effect is shown to be just as important following long and short periods of no practice.

d. The type of initial training (amount of verbal guidance) is unrelated to retention performance when proficiency level after original learning is held constant.

e. Retraining administered under conditions of distributed practice was superior to that administered under mass practice, though on retesting 1 week later no difference was noted between the two retraining procedures.

f. Predictions of individual differences in retention from independent ability measures were negligible. Retention appears more a function of specific task habits acquired, than of subjects' ability traits developed prior to training.

g. The correlation between individuals' performance levels at the end of initial training and after the retention interval was quite high, varying from a low of r = .80 for Group I (no formal guidance training) at the 24-month interval to a high of r = .98 for Group II (formal guidance training) at the 9-month interval.

3. Conclusions

a. The study confirms, using a complex continuous control task, the evidence from previous studies that perceptual-motor skills are well retained for periods of no practice up to 24 months.

b. The data indicate a substantial loss between 14 and 24 months, but the lost skill was quickly regained through retraining.

c. Level of initial proficiency is a prime determiner of level of skill retention.

d. There is considerable stability of relative skill levels by group members over extended periods of no practice.

4. Comment

This well-designed and executed study lends support to the contention that basic perceptual-motor skills, such as those involved in piloting an aircraft, show relatively little decrement for no-practice periods up to 24 months and that such loss as occurs is quickly restored by retraining. The stability of the individual's performance level over time relative to that of others in his group might, if substantiated for actual flight skills, lend support to a program of selective identification (based on relative proficiency level prior to a non-flying episode) of pilots to be retrained after non-flying periods.

45. Hanley, M.J. Investigation of the Effects of Increased Flying Hours on Naval Postgraduate School Aviator Skill, Knowledge, and Satisfaction: A Comparative Analysis. Masters Thesis. Naval Postgraduate School, Monterey, CA, March 1971.

84. Also available as: Schrady, D.A. and Hanley, M.J. A Comparative Analysis of Proficiency Aviator Skill, Knowledge, and Satisfaction. (Faculty Research Project). U. S. Naval Postgraduate School, Monterey, CA, March 1971.

1. Description

This study sought to examine effects on flight proficiency of a 4-hour per month proficiency flying regimen versus an 8-hour per month regimen. Subjects were Naval aviators who were in CRT status as students at the U. S. Naval Postgraduate School. Three types of data were collected: (a) attitudes toward CRT and the T-1 aircraft; (b) knowledge of T-1 systems and procedures; and (c) inflight performance utilizing a semi-objective flight checklist. Flight performance of the two groups was compared under pre- and post-test design over a period of approximately six months.

2. Results

a. Both the 4-hour and 8-hour CRT groups felt 4 hours per month was inadequate to practice mission skills and maintain proficiency.

b. The 8-hour group exhibited scores on the T-1 systems examination that were statistically significantly higher than those of the 4-hour group.

c. Flight performance scores favored the 8-hour group, but differences were not statistically significant.

3. Conclusions

In spite of the non-significant differences in flight performance, the author concludes that: "The author is of the opinion that the 8-hour group is indeed more skillful than the 4-hour group." This opinion was based on the belief that the significance of differences was obscured by the greater performance variability exhibited by the 8-hour group.

4. Comment

While this is one of the very few studies of proficiency flying in which inflight performance data have been gathered, it suffers from a number of methodological problems. Of course, it is pertinent to choosing among proficiency flying program alternatives, but it has little relevance to the subject of long-term retention of flying skills. However, it was an ambitious study for the circumstances, and its use of somewhat more objective means of assessing inflight pilot performance is a procedure much to be encouraged.

48. Hollister, W.M., LaPointe, A., Oman, C.M., and Tole, J.R. Identifying and Determining Skill Degradations of Private and Commercial Pilots. FAA-RD-73-91, MIT Measurement Systems Laboratory, Cambridge, MA, June 1973.

1. Description

This study sought to measure skill degradation for a sample of 55 non-instrument rated, single-engine certificated private and commercial pilots as a function of several experience factors, primarily indices of recency of flight experience. Ss were administered three test flights during which grades were assigned to flight segments utilizing a six-point subjective rating scale. Flight data were then related to various experience indices through a stepwise regression analysis.

2. Results

a. Overall flight grade was positively related to aircraft type recency.

b. Overall flight grade was positively related to total flight time.

c. Overall flight grade was negatively related to years since certification.

d. Overall flight grade was positively related to time in aircraft type.

e. Overall flight grade was negatively related to pilot's age.

f. The five experience variables used accounted for only 24% of the variance in flight performance.

3. Conclusions

a. Prediction of an individual pilot's skill based only on experience factors is unreliable.

b. The most important experience factor in predicting flight skill is recency of flight experience (defined as approximately the average rate at which the skill is practiced).

c. The logarithm of total time is also useful in predicting skill from experience.

d. Skill decreases as a function of years since certification.

e. No relationships were found between the following factors and flight skill: score on written quizzes; subject's own assessment of skill; geographic factors; and type of initial training.

f. Highest grades were received on those aspects of flight practiced most often, such as preflight and take-off, while lowest scores were received on infrequently practiced aspects such as stalls and instrument flight.

4. Comment

This study presents an interesting approach to skill degradation. The method for computing recency of experience is worthy of note. However, the study design was not set up to examine retention over any specified non-flying interval, other than that one-third of the subjects had an elapsed time since last flight of less than two weeks, a third from two to six weeks, and a third more than six weeks. There was, apparently, no attempt to limit other flying activities during the period of the three data flights, though such flights were entered into recency calculations. Also, as noted at least by inference by the authors, the subjective grading system could have introduced a significant amount of error variance into the flight test data. This study is descriptive, rather than experimental, and, while the results sound logical, the data would require verification before one might assume their generality to all flight situations. There are obvious differences from current USAF flight situations -- a different subject population, lower skill levels, a much simpler flight task, retention time intervals, etc. -- but this study would seem to offer an approach that has merit, and USAF might do well to pursue this research methodology further in a more pertinent flight context.

53. HumRRO Division No. 6 (Aviation). A Test of Synthetic Training in Combat Readiness Proficiency Training. Unpublished Internal Research Report, Human Resources Research Organization, Fort Rucker, AL, June 1974.

1. Description

This was a pilot study of the use of a high fidelity helicopter simulator (no visual system) in programs for maintaining flight proficiency and for retraining after non-flying periods. Three groups of Army aviators received training in the simulator to proficiency levels required to pass the standard instrument checkride. The groups were: (a) aviators holding current cockpit assignments (N = 10); (b) aviators who had been in proficiency flying status, i.e., 80 hours per year (N = 10); and (c) aviators who had been in non-flying status for periods of 9-24 months (N = 10), Each subject received an initial diagnostic checkride in the simulator and then received an individualized, proficiency-paced training program designed to bring his proficiency up to the level required to pass the instrument checkride. Following successful completion of the simulator check, each participant was given the same instrument checkride in the UH-1 aircraft. Each then received a diagnostic contact checkride in the aircraft and such training as was necessary to pass the contact maneuver checkride in the aircraft.

2. Results

a. Mean hours of simulator time required by each group (including 2½ hours devoted to simulator instrument checkrides) were as follows: Group A = 6.2; Group B = 11.4; and Group C = 11.7.

b. Mean instrument hours required in the aircraft to pass the instrument checkride were as follows: Group A = 2.2; Group B = 2.6; Group C = 2.6.

c. Mean contact hours required in the aircraft to pass the contact checkride were: Group A = 1.7; Group B = 2.1; and Group C = 2.6.

d. Variability in total time required among individuals in the various groups was approximately half as great for Group A as it was for Groups B and C, with the bulk of this difference being peculiar to variations in time required in the simulator.

3. Conclusions

a. Aviators in current flying assignments required only about half as much time to reach required proficiency levels as those who had been in proficiency flying or non-flying status. There was little practical difference between the latter two groups.

b. The proficiency losses from the approximately one year of non-flying or proficiency flying are not large in a practical sense (approximately 6 hours retraining time) when compared with times required to reach

proficiency by aviators in current flying assignments.

c. The simulator is an appropriate means to provide virtually all the retraining necessary for normal instrument and contact operations in the helicopter.

d. Through efficient simulator training, proficiency differences among the groups (which were in the expected directions) can be largely confined to the simulator.

e. Achieving proficiency in this helicopter simulator allows prediction with high confidence that the individual can demonstrate proficiency in the helicopter with little aircraft training required.

f. Restoration of instrument proficiency in the simulator provides benefits to contact performance in the aircraft.

4. Comment

This was a small-scale study, and the conclusions must be viewed as suggestive rather than definitive. Nevertheless, it provides evidence that (a) subjects who had engaged in proficiency flying programs were little better off than those who had not flown at all, and (b) both these groups were able to regain necessary proficiency in the simulator and in relatively little time. It is of interest to note that the total simulator plus aircraft time required by Groups B and C (16-17 hours) is very similar to the retraining time reported by non-flying respondents in Wright's study[1/] of helicopter pilots. Of course, it must be kept in mind that this study was concerned only with the establishment or retraining of basic contact and instrument proficiency levels. It did not deal with tactical mission skills such as weapons delivery and nap-of-the-earth flight and navigation. It does indicate, however, a high level of skill retention after extended periods of non-flying and the feasibility of reliance on the simulator as a major retraining means.

1/ Wright, R.H. Retention of Flying Skills and Refresher Training Requirements: Effects of Non-Flying and Proficiency Flying. HumRRO Technical Report 73-22, Human Resources Research Organization, Alexandria, VA, December 1973.

55. Killian, D.C. Pilot Proficiency Retention for United Air Lines Second Officers. United Air Lines, Inc., February 1965.

1. Summary

Questionnaires were administered to 109 second officers who had recently upgraded to first officer status after an average time of 8 years as second officer. Flight managers were also queried concerning the upgrading of these pilots. Findings are difficult to interpret with reference to non-flying retention, because many of the second officers (over half) were flying in military units or in other capacities during their service as second officer. However, the author reports the second officers "had no problem upgrading to the position of first officer." No substantial difference was found in the performance of second officers with less than 1,000 hours and those with more than 1,000 hours. In summary of the retention area, the author states: "It would appear, therefore, that the pilot skills desired of an airline first officer consist of many factors, many of which can be retained and, in fact, enhanced by other activities than actual "stick and rudder" practice."

2. Comment

This study suggests that long-term retention of basic flight skills is good and that a program of simulator training will reinstate skills to acceptable levels. Reference is made to procedures, communications, and instrument flying skills as areas of greatest decrement. However, this study of retention time factors did not have sufficient experimental controls to make the results of great interest to current USAF problems.

57. Kusewitt, J.B. Combat Readiness Training (CRT) Study (U). Report 2-55100/8R-50450. Prepared for the Deputy Chief of Naval Operations (Air), Vought Aeronautics Division, LTV Aerospace Corporation, Dallas, TX, August 1968 (CONFIDENTIAL).

1. Summary

This study was a comprehensive analysis of the Navy's overall flight proficiency program to determine its value, need, and cost effectiveness. Possible improvements to the CRT program were discussed. Most of the information given in the report is unclassified, and only unclassified portions will be discussed here. Data sources of great variety were used, including costs, accidents, refresher training, and a survey of some 1,600 Naval aviators and 324 Naval flight officers concerning the relationship of various CRT alternatives to their career plans. General conclusions were as follows:

a. The CRT program was cost effective, with benefits exceeding costs by a ratio of 3-4 to 1.

b. Lack of a CRT program would have a negative impact on career retainability of Naval aviation personnel.

c. Refresher training savings as great as 37 hours per aviator are possible when CRT and refresher training are in the same model aircraft.

d. Absence of CRT would have a negative impact on force reaction time, voluntary groundings, and accidents in refresher training.

e. Insufficient data existed to ascertain the value of either academic ground training or simulator training to the maintenance of flying proficiency.

2. Comment

This was an extensive examination of Navy CRT programs, perhaps the most extensive examination of any of the military services. It was conducted with an orientation toward developing an improved CRT program, so it is not surprising that it should conclude that CRT is a good thing. The scope of the effort was quite comprehensive, and it seems to have been performed with competence. As with many cost-effectiveness studies, the quality of individual data inputs may be questioned. For example, the method of deriving a "forgetting function" or the assumption that CRAW training time data and grades are unbiased can be questioned. Certainly, the integration of behavioral science research background into the study was minimal. Nevertheless, in spite of the bias toward support of CRT programs and data questions, this was a major effort that was done well, and which provides much worthwhile information and examples of methodology. While its orientation toward behavioral science is minimal, the reader interested in a comprehensive view of proficiency maintenance questions would do well to examine this document.

63. Mengelkoch, R.F., Adams, J.A. and Gainer, C.A. The Forgetting of Instrument Flying Skills as a Function of the Level of Initial Proficiency. NAVTRADEVCEN Technical Report 71-16-18, U. S. Naval Training Device Center, Port Washington, NY, 1960.

1. Description

The objective of this study, which involved a variety of complex simulated flight tasks, was to investigate the effects of amount of training on the forgetting of instrument procedural and control skills. Two groups of 13 subjects each were given 4 hours of classroom instruction, one familiarization "flight," and then either 5 or 10 training flights of 50 minutes' duration. The subject task consisted of IFR flight control and execution of all normal procedures from engine start-up through shutdown of the 50-minute structured flight. A moving base (Link 1-CA-2) flight simulator configured to represent the SNJ aircraft was used. After a four-month interval, four retraining trials were given. Performance parameters measured included 120 procedural items and five flight control items measured every 10 seconds; altitude, bank, airspeed, level-off at altitude, roll-out on new heading. The 120 procedures items consisted of three categories of procedures: (a) static - those not requiring concurrent flight control; (b) dynamic - those requiring concurrent flight control; and (c) emergency - those requiring concurrent flight control and cues for which were presented without warning.

2. Results

a. Procedural skills showed significant retention losses over the four months period for both training groups. Loss was relatively greatest for static procedures and least for dynamic procedures.

b. Statistically significant losses were shown for altitude and airspeed control for both groups and for bank control for the group with less original training. However, the mean error increase in these parameters was not of practical significance (e.g., altitude <20 ft.; bank <0.5 degrees; and airspeed 1-2.4 MPH).

c. Groups with five and ten 50-minute training trials showed similar amounts of forgetting for most measures of flying proficiency. This meant that the group with the greatest amount of initial training had the highest performance level after the retention interval, since its performance at the end of training was better.

d. The number of trials taken to relearn to the level of the proficiency attained on the final training trial is fewer than that taken originally.

e. The number of trials taken to relearn is a positive function of the amount of initial training.

f. One difference from laboratory studies using relatively simply procedural and training tasks was that the relatively complex Operational Flight Trainer (OFT) tasks required a much longer time to relearn.

3. Conclusions

a. "The most important implication for operational flight training is that procedural responses show retention losses that are not only statistically but practically (operationally) significant whereas measures of proficiency (loss) for flight parameters are operationally insignificant throughout, even in the instances when they are statistically significant."

b. "The findings of this study strongly suggest that programs directed toward the maintenance of flying proficiency should focus on the training of procedures."

c. Many procedures can be taught in a classroom with simple training aids, but others can profitably use either a cockpit procedures trainer, a general instrument flight trainer, or an OFT.

d. When the costs of an OFT are not feasible for a program, a combination of general instrument flight trainer and a cockpit procedures trainer should be considered.

4. Comment

This is one of the best of the direct studies of flight task retention, though it must be kept in mind that all data concern simulation performance. However, generalization of the results to aircraft performance is probably reasonable. The task studied was complex and realistic and the performance measures used were comprehensive. The principal deficiencies of the study, as it relates to current USAF concern, is that level of training did not approach that of the typical experienced USAF pilot entering a non-flying episode and the four-month retention interval is much shorter than the typical non-flying period of concern. Even so, the conclusion concerning the differential forgetting of procedural and control skills, and means of maintaining proficiency or reinstating it, are pertinent to current USAF problems.

73. Naylor, J.C., Briggs, G.E., and Reed, W.G. The Effects of Task Organization, Training Time, and Retention Interval on the Retention of Skill, AMRL-TDR-62-107, 6570th Aerospace Medical Research Laboratories, Air Force Systems Command, Wright-Patterson AFB, OH, September 1962.

74. This research also reported in: Naylor, J.C., Briggs, G.E. and Reed, W.G. "Task Coherence, Training Time, and Retention Interval Effects on Skill Retention." J. Appl. Psychol., 1968, 52, 386-393.

1. Description

As part of USAF research on long-term retention, three variables (amount of training, task organization, and length of retention interval) were examined for their influence on long-term retention. The criterion task involved time-shared activity between a three-dimensional compensatory tracking task and a discrete procedural task. Eight groups of 16 subjects each received (a) 2 or 3 weeks of training on (b) tasks of high or low organization, and (c) were tested after retention intervals of 1 or 4 weeks. Task organization of the secondary procedural task had to do with the spatial predictability of a group of signal lights being monitored.

2. Results

a. Learning is more rapid with high organization tasks.

b. Retention varied directly with level of training.

c. Low task organization produced lower retention only for low levels of training.

d. For the procedural task, only ommissive errors showed relationship to level of training, task organization, and retention interval.

3. Conclusions

a. Amount of training is the most important variable in retention of both tracking and procedural skills.

b. Absolute level of skill retained is related to task organization principally through proficiency level attained in original training, but rate of loss of retention (relative to original performance level) is not related to task organization.

c. Similar retention-decrement effects were found for both the procedural and tracking tasks.

4. Comment

These results confirm those of many other investigators concerning the great effect of level of performance on retention. The failures to find that task organization gave a consistent main effect and that procedural

response time was related to the experimental variables were surprising. While these results are not directly applicable to current USAF flight skill retention problems, they do provide a framework for predicting or understanding aspects of skill retention in terms of relation to training, time, and task organization.

83. Schrady, D.A. Activity Levels and Aircraft Types in Jet Proficiency Flying (CRT) at NALF Monterey--Data Acquisition at Four Hours Per Month in the T-1A Airplane. Report NPS-55500091A, Naval Postgraduate School, Monterey, CA, September 1970.

1. Summary

As a result of concern by the Navy, the GAO, and the Congress over CRT flying requirements for pilots in student status, such as those at the Naval Postgraduate School (NPS), the NPS undertook to study aspects of CRT in 1970. The concern was comparison of CRT in the T-1A aircraft and a leased, business jet aircraft, and comparison of 48-hours per year and 100-hours per year CRT groups. This report describes the basic data gathering methods and instruments that were to be used in the study. As such, it does not present analyses pertinent to CRT or to long-term retention questions. It does present the semi-objective inflight checklist used to gather performance data. Data are presented dealing with use of the checklist to derive flight performance scores. It is described here as background for data presented in Hanley's [1]/ 1971 thesis in which inflight performance comparisons are made for the two CRT level groups.

2. Comment

This report presents no data pertinent to CRT programs or to long-term retention of skills. It is significant, however, in setting forth a method for semi-objective inflight performance measurement to be used in more direct studies of CRT and retention. In view of the dearth of objective flight performance data in CRT and long-term flight skill retention studies, it is a welcome addition, though the methodology cannot be considered fully developed.

1/ Hanley, M.J. Investigation of the Effects of Increased Flying Hours on Naval Postgraduate School Aviator Skill, Knowledge, and Satisfaction: A Comparative Analysis. Masters Thesis. Naval Postgraduate School, Monterey, CA, March 1971.

85. Seltzer, L.Z. A Study of the Effect of Time on the Instrument Skill of the Private and Commercial Pilot. Report No. FAA-DS-70-12, Department of Transportation, Federal Aviation Administration, Washington, DC, April 1970.

86. Also published in revised form as: Seltzer, L.Z. and McBrayer, J.D. A Study of the Effect of Time on the Instrument Skill of the Private and Commercial Pilot. Report No. FAA-DS-70-12. Parks College of Aeronautical Technology of St. Louis University, Cahokia, IL, March 1971.

1. Description

Flight performance of a sample of 66 private or commercial pilots (none of whom was instrument rated, a former military pilot, or certificated prior to 1960) was examined to assess the effect of time on their instrument proficiency. By "time," the author is referring to years since certification. Flight proficiency was evaluated by means of a subjective instrument checkride in which various elements were rated on a five-point scale. For those elements rated "below average" or "unsatisfactory," instruction was given and time noted. Subsequently, a second checkride was given. No real data analyses are presented, only a few descriptive plots and tables.

2. Results

Due to the method of data presentation used in this report, it is difficult to identify specific results. However, the following are noted:

a. The best instrument flight performance by private pilots was on "straight and level" and "level turns," while they were poorest on "trim control," "power control," and "stall and spiral recovery."

b. Commercial pilots did well on level flight maneuvers and were weaker on climbing and descending turns.

c. Private pilot performance as a function of time since certification seems to show minor, random variation about the so-called "average" score.

d. Commercial pilot performance seems to show a gradual decline from a level somewhat above "average" at certification to an asymptotic "average" level at about 5.5 years after certification.

3. Conclusions

From the results, Seltzer draws the following conclusions:

a. "There is a definite loss of instrument proficiency with time for the private pilot and to a lesser degree for the commercial pilot."

b. "This loss of proficiency is attributed partly to the motor skills of the individual pilot and also to his lack of knowledge."

c. "A majority of pilots did not seem to have a thorough understanding of the primary instrument indications experienced in Straight and Level Flight, Climbing, and Descending Turns."

d. "The time required to regain the instrument proficiency in any case, varied with the pilot, . . . For the private pilots, the average time to regain proficiency was 2½ hours of flight instruction and 50 minutes of ground instruction; for the commercial pilot, it was 1½ hours of flight instruction and 25 minutes ground instruction."

4. Comment

This study adds nothing to our knowledge of flight skill retention. It was a very poorly conceived and executed effort and was not designed to examine non-practice as an independent variable. Flight performance measures are very suspect, and it is virtually impossible to tell just what was done or to evaluate the results from the presentation in the report. The study is reviewed here in some length only because of the great discrepancy between the seeming pertinence or promise of the title to USAF concerns, on the one hand, and the actual barrenness of the report in terns of content, conclusions, and scientific rigor.

This report was revised and republished in March 1971 under the same title and report number, but with James D. McBrayer added as a second author. The revised version presents a good deal more in the way of data analysis and deletes some of the interpretations given in the original to explain year-to-year variations in certain of the data. The revision is an improvement, but the basic weaknesses of the study remain.

87. Shaver, G.J. Proficiency Flying in the USMC: An Analysis. Research Study. Air University, Maxwell AFB, May 1971.

1. Summary

This research study reviews a variety of items pertinent to USMC proficiency flying. No new primary data are presented, but the author presents Navy accident data for CRT and non-CRT aviators during their first and second 3-month periods of Combat Replacement Air Wing (CRAW) training. Accident rates per 10,000 hours during the first 3-month period were 0.883 and 1.269 for the CRT and non-CRT groups, respectively (jet pilots only; rates were 0.339 and 0.487 for non-jet groups). During the second 3-month period rates dropped to 0.620 and 0.637 for the CRT and non-CRT jet pilot groups (0.236 and 0.239 for non-jet groups). While the lower accident rate in CRAW training would seem to support the need for CRT flying, the author correctly notes that accidents that occurred during CRT flying should be included in the CRT group data for a meaningful comparison. Shaver questions the need for and effectiveness of CRT programs in general and notes that no definitive data exist on proficiency programs because ". . . lack of a controlled environment seriously degrades any reliable findings. A controlled study should be undertaken." He observes that it requires about 550 hours of an aviator's time (the equivalent of 11 50-hour work-weeks) for him to get the required 100 hours per year of CRT, time that could better be devoted to his primary (i.e., non-flying) duties.

2. Comment

This is a good secondary review source. The author has examined the subject fairly thoroughly. While he does not treat the subject of long-term retention of flight skills, he seems of the opinion that retention would not be a problem in a program of no-CRT followed by retraining, and that such a program would be cost effective.

88. Sitterley, T.E. Degradation of Learned Skills -- Static Practice Effectiveness for Visual Approach and Landing Skill Retention. Boeing Document D180-17876-1, The Boeing Aerospace Company, May 1974.

89. Sitterley, T.E. and Berge, W.A. Degradation of Learned Skills -- Effectiveness of Practice Methods on Simulated Space Flight Skill Retention. Boeing Document D180-15081-1, The Boeing Company, July 1972.

90. Sitterley, T.E., Zaitzeff, L.P., and Berge, W.A. Degradation of Learned Skills -- Effectiveness of Practice Methods on Visual Approach and Landing Skill Retention. Boeing Document D180-15082-1, The Boeing Company, October 1972.

1. Description

The purpose of this series of three related studies was to examine long-term retention of skills in the flying of manned spacecraft. All three studies involved simulated spacecraft relevant to the NASA manned spaceflight program. In the first study, the task involved manual control of the simulated spacecraft from lift-off to orbit insertion. Retention of procedural and control skills was examined for intervals ranging from one to six months. Nine groups of five subjects each (predominantly non-pilots) allowed study of several methods of retraining. The last two studies involved the simulated descent, approach, and runway landing of the spacecraft after assumed de-orbit and reentry. Both instrument and far-field visual cues were presented. All subjects were former pilots. Four groups of five subjects each were used to study effects of retraining methods. These studies, sponsored by NASA, utilized a complex task with a fairly wide variety of stimulus characteristics and response demands. Methods of retraining in the first study were (a) dynamic warmup (hands-on), (b) distributed rehearsal (static, non-hands on), and (c) immediate rehearsal (static, non-hands on). Methods in the second study were (a) static rehearsal (non-hands on) and (b) dynamic display rehearsal (non-hands on), while the third study utilized an improved static retraining method (non-hands on) that involved heavy emphasis on outside visual cues.

2. Results

a. Degradation of continuous control skill was moderate for the first three months, but increased sharply at that point, with magnitude of error for most control parameters exceeding end-of-training levels by a factor of two to three.

b. Procedural tasks showed strong degradation in time-to-execute after only one month of no practice (five times end-of-training value), and then showed a further sharp degradation after the third month (reaching 17 times end-of-training value after four months).

c. Relative skill degradation was found to be greater for instrument flight skills than for those involving far-field visual cue referents, though this finding was not subjected to statistical test, nor was task loading equated for the two types of task situations.

d. Rehearsal practice distributed throughout the retention interval was more beneficial than only immediate rehearsal just prior to retraining.

e. Rehearsal (distributed) was sufficient to maintain procedural skills at near-original learning performance levels for up to six months.

f. In retraining after four months, the static rehearsal method was found least effective, dynamic display next, and the improved static retraining method (which emphasized visual cues) was found most effective. The latter method maintained skills at initial training levels with no decrement, essentially, after the four month period.

g. Far-field visual cues are important in maintaining skills, but their representation in static form was as effective as when they were represented dynamically.

3. Conclusions

a. Significant performance decrements occur in both procedural and continuous control skills unless some form of practice or rehearsal is interspersed during the retention interval, with the effect being relatively greater for procedural tasks.

b. Both procedural and control task skills can be maintained at relatively high levels with fairly simple, static rehearsal techniques.

4. Comment

This series of well-designed and executed studies utilized a task of complexity and content similar to that of the USAF pilot. The data show that significant degradations in skills do occur in the absence of practice, but the highly favorable results with static rehearsal techniques suggest that USAF pilots might maintain flight skills at relatively high levels during non-flying periods through use of such procedures. The use of such techniques in conjunction with the use of flight simulators or other devices should allow significant reductions in retraining costs and is an area well worth exploration.

91. Smith, J.F., and Matheny, W.G. Continuation Versus Recurrent Pilot Training. AFHRL-TR-76-4, Air Force Human Resources Laboratory, Brooks AFB, TX, May 1976.

1. Summary

In response to current USAF concern over continuation (i.e., proficiency) training programs, the availability of resources to support such programs, and the readiness of the rated supplement force, the Human Resources Laboratory conducted a survey of the literature on pilot skill retention and developed pertinent conclusions from that literature.

Some 15 references are reviewed briefly in the report. In addition, six bibliographic items are listed, though these are not reviewed. Of considerable interest is the authors' inclusion of data and discussion of unpublished material [1] dealing with the retraining of returned USAF POWs from Southeast Asia. These POW returnees had from 300 to over 7,000 hours of total flight time before being shot down, and time as POW varied from 13 to 102 months. These pilots were retrained by the Air Force in a highly individualized training effort to bring these pilots back up to required proficiency levels. All training took place at a single location.

Due to the period of cessation of bombing of North Vietnam during the conflict, two distinct groups of POWs resulted. Data are presented for two groups: (1) those whose non-flying episode ranged from 13 to 34 months (M = 19 months); and (2) those whose non-flying period ranged from 69 to 102 months (M = 84 months). Retraining flight time for the 21 pilots included in the shorter episode group averaged 38.4 hours, while average time for the 39 pilots in the longer episode group averaged 45.4 hours. Average retraining time for all returnees was 42.2 hours. Grouping the pilots into three categories on the basis of total flight time (Low = 300-1,000 hours; Mid = 1,001 - 2,000 hrs.; and High = 2,001 - 7,250 hrs.) resulted in statistically significant differences in retraining time between the low-time group and the other two groups. Mean retraining flight hours were 48.5, 35.3, and 41.6 for the Low, Mid, and High groups, respectively.

[1] No formal publication dealing specifically with POW pilot retraining is known to the present author. However, another exposition based on the POW retraining data, one somewhat more extensive than that of Smith and Matheny, is contained in: Armstrong, M.B., Bleymaier, J.S., Hinkel, J.F., Levins, R., and Sheppard, R.R. Flying Skill Retention and Proficiency Flying. Research Study Report No. 0095-75, Air Command and Staff College, Air University, Maxwell AFB, AL, May 1975.

Based on the studies reviewed and the POW retraining data, the authors identify the following as significant findings:

(a) Motor skills associated with VFR flight are retained longer and regained much more quickly than instrument or procedural and verbal skills.

(b) Inactivity for one year results in near maximum loss of skills (one estimate is 90 percent), and subsequent periods of inactivity add little to average upgrade time requirements.

(c) If instrument flight skills are maintained at a high level, contact flight skills tend to remain at an acceptable level.

(d) Overlearning promoted improved retention of all categories of skills.

(e) Simulators are effective in either learning or relearning procedural and verbal tasks and instrument flying skills, and their use should significantly reduce the hours noted in paragraph (f), following.

(f) Retraining of contact and instrument aircraft flight skills after extended periods of inactivity (13 to 102 months) can be completed in an average of 45 aircraft hours or less per student.

(g) Pilots of low experience levels (less than 1,000 hours) will require more hours to become recurrent, but the overall average should remain below 50 hours per pilot.

Based on these findings the authors conclude that abolition of continuation training could result in significant cost savings to USAF, and that recurrent training could be delayed almost indefinitely until required by new job assignment or other USAF needs.

2. Comment

While the authors describe their review as of limited nature, they have touched on the more significant available documents. The provision of the POW retraining data is a valuable addition to the literature. The depth with which the various studies are reviewed in the Smith-Matheny report is minimal (i.e., the amount of detail in their written discussion), but their conclusions seem well-warranted by the present author's review of the literature. However, as Smith and Matheny note, available data are meager, and more data are needed to permit informed USAF policy.

92. Smittle, J.H. "Current" vs. "Stagnant" Jet Pilots' Response Time: A Comparison. Masters Thesis. U. S. Naval Postgraduate School, Monterey, CA, 1973.

1. Summary

This study compared control response times of aviators who had flown within the last 60 days with those of aviators who had not flown within 60 days. The stimulus was tachistoscopic exposure of slides of the vertical gyro indicator depicting unusual aircraft attitudes. Results showed no significant differences between current and stagnant groups. Pilots with 1,700 hours or more had significantly faster reactions than those with less time.

2. Comment

This study is of little value to the retention question. Methodology was weak.

102. Tice, R.K. Navigator Proficiency Flying. Research Study. Air University, Maxwell AFB, May 1973.

1. Summary

The focus of this study was navigator proficiency flying, rather than pilot programs. No new data are presented, but a number of studies are reviewed as the author develops his general thesis that USAF proficiency programs for navigators in the rated supplement are not effective, not required, and unduly costly. He cites data on the retraining of 31 B-58 Defensive Systems Operators as Navigators at the KC-135 navigation CCTS. Only one of this group had ever flown as a navigator after being rated, all having been EW specialists. Failure rate in the navigator CCTS program for the group was only 6.7% versus 15% for regular navigator students in the program. The author concludes that there had been no decline in the group's navigator skills during their extended period as EW apecialists.

2. Comment

While this study does not deal directly with pilot skills, there is such commonality between pilot and navigator tasks that the author's review has some pertinence. Obviously, it can be argued that the B-58 EW people had been flying and performing jobs that had much in common with navigator requirements. However, this suggests that transfer from one job or task to another can maintain certain skills over extended periods and that non-flying skill maintenance alternatives (e.g., use of simulators) may be sufficient during extended periods of non-flying duty.

107. United States Air Force. A Study of Pilot Proficiency Flying (Saber Wings). Volumes I and II. Assistant Chief of Staff, Studies and Analysis, Hq., USAF, Washington, DC, 1969. (FOR OFFICIAL USE ONLY).

1. Summary

This effort examined USAF proficiency flying programs and examined alternative programs for maintaining proficiency. While the reports are FOR OFFICIAL USE ONLY, only open end unclassified portions will be discussed here. CCTS training data were used to examine relationships of variables such as age and flying experience to CCTS training performance. In addition, some 10,400 pilots were surveyed concerning their opinions and experience relevant to proficiency flying programs. While the study did not address the area of flight skill retention experimentally, it did indicate that age was a significant factor in CCTS performance in some situations, and that similiarity of aircraft background to that of CCTS training (e.g., fighter-fighter, or airlift-airlift) was also a significant factor. Pilot opinion, nor surprisingly, favored proficiency programs involving more hours and combat-type aircraft.

2. Comment

This was an extensive effort by the Air Force, one that has influenced the thinking of many persons about proficiency flying. In consonance with the general orientation of the Air Force at the time of the study, the study leans toward improving proficiency programs within the same general structure. Certain of the data addressed (e.g., relationship of age to CCTS performance) are interesting and should be investigated further. The validity of CCTS grade data for determinations related to skill retention is unknown and should be investigated. The pilot opinion data must be examined carefully in light of the situation that existed at the time of the study (i.e., fuel, dollar, and resource availability) before being generalized for applicability to other times and circumstances. Saber Wings was an ambitious effort which has elicited both emotion and serious thought with reference to USAF proficiency flying requirements.

114. Wilson, W.B. The Effect of Prolonged Non-Flying Periods on Pilot Skill in Performance of a Simulated Carrier Landing Task. Masters Thesis. Naval Postgraduate School, Monterey, CA, September 1973.

1. Description

The effects of flight currency and experience on performance of a simulated carrier landing task were examined in this study. Fifteen aviators were divided into three currency groups: (a) current (i.e., flown within past 60 days); (b) one-year stagnant (10-17 months no-fly); and (c) two-years stagnant (25-30 months no-fly). Subjects were also classified into three experience groups: (a) low (<500 hours); (b) intermediate (1100-1400 hours); and (c) high (>1900 hours). The task was a simulated carrier landing involving a minimal aircraft simulation and a computer image visual display of the carrier. Performance score was based on point of touchdown, rate of descent at touchdown, lateral error, and airspeed.

2. Results

(a) No significant difference as a function of currency.

(b) Such degradation as occurred over time was procedural, not tracking skills.

(c) The Low Experience group performed significantly less well ($p<.10$) than did the other two groups.

3. Conclusions

(a) Tracking skills remain intact over long periods of no flying. Degradation is largely in procedures.

(b) Experience does influence tracking skill. Therefore, the RAG training syllabus should be individualized on the basis of experience.

4. Comment

This is a good effort under the circumstances (i.e., as a Masters thesis with limited resources), but it is restricted on several grounds. The simulated task was not complex, and its representativeness of operational flying can be questioned. However, the experimental design and data analysis techniques were appropriate. All in all, the data and results are judged as pertinent to current USAF skill retention problems.

116. Wright, R.H. Retention of Flying Skills and Refresher Training Requirements: Effects of Nonflying and Proficiency Flying. HumRRO Technical Report 73-32, Human Resources Research Organization, Alexandria, VA, December 1973.

1. Description

The objectives of this study were to develop data concerning the effects of non-flying periods on aviator skill retention, to assess the effectiveness of Army proficiency flying programs, and to develop implications for future proficiency maintenance or retraining programs. Survey forms were sent to some 5,500 Army aviators concerning their experiences relative to retention of flight skills during non-flying or "minimums-only" episodes of six months or longer and their retraining experiences after such episodes. Some 525 returns were received, of which data analyses were performed on 117 in the "minimums-only" category and 58 in the "no-flying" category. Respondents were asked to rate their flying ability on some 20 specific aspects or components of flying skill at three points in time -- when first rated, just before the no-flying or minimums-only episode, and just after the episode. An 11-point anchored rating scale was used in these ratings. In addition to providing data concerning training actually received after such episodes in preparation for return to flying duties, respondents were asked to provide estimates of time required to regain ability level at first rating and ability level for pilot-in-command duties.

2. Results

a. Flying minimums resulted in only a slightly lower rate and amount of loss of flying skill than did not flying at all.

b. About 90% of the loss in flying skill that occurs over extended periods of no-flying or minimums occurs within the first 12 months.

c. Respondents indicated higher pre-episode skills in visual (VFR) than in instrument (IFR) flying, but rate and amount of decline in skill was about the same for VFR and IFR skills.

d. While most respondents indicated VFR skills remained well above minimum acceptable levels for no-flying or minimums episodes up to 36 months in length, for IFR skills approximately half reported being below minimum acceptable level within 12 months of no-flying or minimums.

e. The effect of proficiency flying on retraining requirements was small -- a difference of only 2 hours in training actually received by the "minimums-only" and "no-flying" groups, and a difference of estimated training required to assume pilot-in-command duties of only 7 hours for the two groups.

f. Those who flew minimums in light proficiency aircraft reported receiving an average of 1.2 hours more retraining instruction after the

episode than did those who did no flying at all, while proficiency flying in operational aircraft reduced retraining hours received by 1.4 hours, as compared with no flying.

g. Pilots of moderate experience levels (500 - 2,000 hours) reported receiving about 3 hours more retraining instruction after an episode than did those of lesser or greater amounts of experience.

3. Conclusions

a. Large losses in flight skill occur over time whether or not proficiency flying is performed.

b. VFR skills generally remain acceptable for up to 3 years, but IFR skills may become unacceptable in only one year.

c. IFR skills should receive primary attention in proficiency flying and retraining programs.

d. Performance decrement curves for flying skills are similar to those for other skills, with most decrement occurring within the first year and little further decrement after that point.

e. Refresher training given more than six months prior to resuming operational flying duties will have little value.

f. Proficiency flying or refresher training in aircraft dissimilar to operational aircraft may result in habit interference and negative transfer.

g. Various simulators and training devices would seem to offer the most cost effective means of maintaining proficiency during non-flying episodes.

4. Comment

This study is probably the most extensive and comprehensive examination of the effects of no-flying or minimum flying episodes on the skills of a military pilot population to date. It has raised serious questions about the effectiveness of proficiency flying programs, specifically, and even about the requirement for such programs, generally. This latter observation stems from the very small magnitude of difference in actual retraining reported by no-fly and proficiency-fly groups, and the small difference in the amount of retraining perceived as needed by these two groups.

This study suffers in two areas that characterize most of the extant attempts to study flight skill retention. First, the data are not actual objective measures of inflight performance, being, rather, self-estimates of proficiency as recalled by the pilot. The cost and administrative difficulty of securing actual, sound inflight proficiency measures before and after episodes of meaningful length have plagued most investigators. The second problem is that of securing enough subjects to obtain adequate size samples to cover variables of interest such as flight experience, age, aircraft/mission factors, length of episode, pre-episode skill level, and the like.

Nevertheless, Wright has provided data of interest. The data are generally consonant with the academic literature and have specific action implications within the Army context. However, it must be recognized that USAF flight skill retention problems have many facets that differ from those of the Wright study. While it is likely that the general implications of this study are quite applicable to USAF concerns, it is clear that the specifics cannot be explicated to the USAF situation in terms such as hours of retraining required. The study does, though, suggest that extended no-flying episodes followed by appropriate retraining activities can return pilots to the cockpit who will be effective.

117. Youngling, E.W., Sharpe, E.N., Ricketson, B.S., and McGee, D.W. Crew Skill Retention for Space Missions up to 200 Days. McDonnell-Douglas Astronautics Company, Eastern Division, Report F766, December 1968.

1. Description

As part of studies of long term space missions, effects of level of training, cloud cover, target motion difficulty level, and retention interval on performance of an image motion compensation task were examined. Retention intervals were 30, 90, and 200 days. Half the 96 Ss (male company engineering and computer personnel) received 60 initial training trials, and the other half received 120 trials. After the retention interval, each S received 25 trials to allow evaluation of both retention and reacquisition performance.

2. Results

a. Amount of original training was a significant factor in amount of performance loss. The 60 trial group lost an average of 5.46 seconds time-on-target as compared with only 2.41 seconds for the 120 trial group. However, no main effect was shown on reacquisition time.

b. A linear relationship between length of retention interval and amount of performance loss was found. Loss was 1.33 seconds for the 30-day interval, 3.28 seconds for the 90-day interval, and 7.19 seconds for the 200-day interval. Retention interval had similar effect on both levels of training, with losses of the 60-trial group being approximately twice as great as those of the 120-trial group at each retention interval. Length of retention interval had an effect on skill reacquisition time with the 200-day group requiring significantly more retraining than the other two groups who did not differ from one another.

c. Atmospheric degradation did not affect retention or reacquisition as a main effect, but did interact with other variables.

d. Performance loss was found to vary inversely with target motion difficulty, i.e., performance under the more difficult motion condition showed less decrement over time than under the less difficult task condition. No difference was found in reacquisition times for the various difficulty levels.

3. Conclusions

a. Retention increases as a function of amount of original training.

b. Retention decreases linearly as a function of length of no-practice interval.

c. In this task many of the interactions among the independent variables were significant.

4. Comment

The rather restricted nature of the task studied here makes these results of minimal direct use in the understanding of USAF pilot skill retention problems. The study was well designed and executed and was quite pertinent to space flight concerns. The finding that more difficult skills were better retained was unexpected, but the authors state that it ". . . may easily be an artifact of the difficulty level measurements."

11. Becker, T.T. Proficiency Flying. Thesis, Air War College, Maxwell AFB, AL, June 1965.

The author reviews USAF proficiency flying programs and concludes it is an inappropriate and costly form of incentive pay. He recommends a revised manpower program that recognizes a less than full career as a rated officer.

23. Buckout, R., Naylor, J.C., and Briggs, G.E. Effects of Modified Task Feedback during Training on Performance of a Simulated Attitude Control Task after 30 Days. Technical Documentary Report, AMRL-TDR-63-125, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1963.

Retention over a 30-day period was shown to be enhanced by higher levels of initial training. Effects of visual and auditory noise were also examined.

31. Fullmer, W.M. Impact of Pilot Flight Excusal Program on Indirect Mission Support Flying. Professional Study No. 4927, Air War College, Maxwell AFB, AL, April 1973.

The author reviews USAF proficiency flying programs and recommends more efficient use of indirect mission support flying. No data are presented, and the report does not add to our information concerning long-term retention.

36. Girling, W.D. Proficiency Flying: An Analysis. Research Report, Air Command and Staff College, Air University, Maxwell AFB, AL, May 1965.

Proficiency flying is reviewed in terms of its history and utility. The author concludes it is inappropriate, costly, and detracts from performance of staff officers in non-flying jobs.

43. Grodsky, M.A. and Lutman, C.C. "Pilot Reliability and Skill Retention for Spaceflight Missions." Air University Review, May-June 1965, 16, 22-32.

This article presents a preliminary report of a joint NASA/USAF study of long-term retention of spaceflight pilot skills required for lunar landing missions. A detailed report of this effort is given by Cotterman and Wood in their 1967 report. 1/

1/ Cotterman, T.E. and Wood, M.E. Retention of Simulated Lunar Landing Mission Skill: A Test of Pilot Reliability. Technical Report No. AMRL-TDR-66-222, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, April 1967.

46. Hansen, A.G. Analysis of Pilot Proficiency and Excusal Programs. Professional Study No. 4601, Air War College, Maxwell AFB, AL, April 1972.

The author reviews the history of proficiency flying programs, relates them to the manpower requirements of TOPLINE, and concludes that proficiency flying programs are not effective. This is an analytical study and adds no new data or information concerning long-term retention of flight skills.

54. Jakubczak, D.R. Proficiency Flying for Rated Supplement Navigators: A Necessity? Research Study, Air University, Maxwell AFB, AL, May 1973.

Navigator proficiency flying programs are critically examined, and the author says the proficiency program for navigators is a waste of time and money ($6.2M/yr.; N=500).

97. Snow, J.H. An Analysis of the USAF Proficiency Flying Program. Thesis, Air Command and Staff College, Air University, Maxwell AFB, AL, June 1965.

The author looks at mission support aircraft used for proficiency flying. He concludes that the T-33 and T-39 have only limited mission support potential, and that USAF needs a new light transport aircraft to replace the C-47 as a mission support, proficiency aircraft.

110. Wellington, R. Proficiency Flying: Outlook for the 1970s. Professional Study No. 4749, Air War College, Maxwell AFB, AL, April 1972.

This document gives a good history of USAF proficiency flying from 1913 to 1971. For example, the Baker Board (1934) set 100 hours per year as minimum; the Hook Commission (1948) discussed "hazard pay;" Congress, in the Defense Appropriations Act for FY 1952 (PL 179), stated "no fly, no flight pay;" the Strauss Commission (Sept 1952) established the Central Flight Status Selection Board to screen continuance on flying; etc. The author reviews the PRC Proficiency Flying Study (1967); Saber Wings (1969); and the LTV CRT Study (1968). Based on these and a variety of other sources, the author concludes: (a) Aircraft operating costs, not flight pay, are the issue now with Congress; (b) Congress dislikes large numbers of senior officers in proficiency flying status; (c) Fear of loss of middle and upper level input is the dominant factor in flight input policies; and (d) There is no measure of effectiveness of USAF proficiency flying, and USAF defense of the program to Congress is weak.

IV. NON-FLIGHT SKILL RETENTION STUDIES

A number of studies were identified that deal with the subject of skill retention, but in a non-flight setting. Many of these deal with motor skills or procedural skills that are conceptually related to flight tasks and have been selected for inclusion in this section. Studies of verbal skill retention have not been covered for reasons previously cited.

Many of the efforts reported in this section deal with general skills (e.g., tracking) that are obviously pertinent to flying, or with the retention of procedural task skills. While the decisions for inclusion of a given study in Section III or Section IV were a bit arbitrary at times, both sections deal with retention studies and are, therefore, of interest with reference to USAF concern over long-term pilot skill retention.

REFERENCES INCLUDED IN SECTION IV

Formats A & B

Format C

Format C

33. Gardlin, G.R. Judgment of Skill Retention. Doctoral Dissertation, University of Washington, 1971. (University Microfilms).

1. Summary

Sixty male subjects learned a perceptual-motor task (two-hand control of rolling a marble through a maze) to a high skill level. After intervals of 1, 3, or 6 weeks, subjects gave self-estimates of residual performance level and number of trials that would be required to reach former performance levels. Results indicated subjects gave inflated judgments of their own skill levels after the retention interval and that they were insensitive to the amount of retraining required to regain proficiency.

2. Comment

While the task, subject population, and retention intervals used are quite different from those of concern to USAF with reference to long-term flying skill retention, these results raise questions about the use of self-estimates of residual proficiency, amount of skill decrement, or amount of training required to regain proficiency in studies of flight skill retention. Because of the difficulty of collecting actual inflight measures of flying proficiency after no-flying periods, many flying skill retention studies have been forced to use such self-estimates. While the present results do not warrant rejection of that methodology, they do call it into question and argue strongly for future USAF investigation of this area.

37. Goldstein, D.A. and King, W.J. Transfer Retention for Verbal and Motor Tasks. Technical Report U411-61-064, Electric Boat Division, General Dynamics Corporation, Groton, CT, April, 1961.

1. Summary

Transfer retention effects over no-practice intervals varying from 10 minutes to 4 months were examined for a verbal task and a motor task. The general concern was with determination of desirable characteristics for transfer from a training task (e.g., a simulator) to an operational task as a function of time. Results indicated that changing either the stimulus or response aspects of the verbal task decreased transfer over all time intervals, whereas for the motor task the stimulus aspects can be changed (within limits) without significant effect as long as the response aspects remain compatible. However, as the no-practice interval increases, the relative decremental difference between stimulus change and response change effects decreases for the motor task.

2. Comment

This study used very simple tasks, a factor that may limit its applicability. However, the authors conclude the following with reference to transfer effects: (1) for verbal tasks consisting of discrete stimulus-response units (e.g., paired associates), the characteristics of the training task should closely correspond to those of the operational task, regardless of length of time between training and task performance; and (2) that for motor tasks involving continuous tracking, the characteristics of the stimulus during training can differ somewhat from those of the operational task, if the response elements are common, without serious effect for periods up to one week -- beyond one week, both stimulus and response can be changed. This study adds little to our practical knowledge of long-term retention.

40. Grimsley, D.L. Acquisition, Retention and Retraining: Effects of High and Low Fidelity Training Devices. HumRRO Technical Report 69-1, Human Resources Research Office, Alexandria, VA, February 1969.

41. Grimsley, D.L. Acquisition, Retention and Retraining: Group Studies on Using Low Fidelity Training Devices. HumRRO Technical Report 69-4, Human Resources Research Office, Alexandria, VA, March 1969.

42. Grimsley, D.L. Acquisition, Retention and Retraining: Training Category IV Personnel with Low Fidelity Devices. HumRRO Technical Report 69-12, Human Resources Research Office, Alexandria, VA, June 1969.

1. Summary

In this series of related studies, the effect of device fidelity on the acquisition, retention, and retraining of missile system procedural skills was examined. Devices varied from a high fidelity representation of the Nike-Hercules control panel to an artist's representation of same. Retention over four- and six-week intervals was studied. Results showed no effects of device fidelity on acquisition, retention, or relearning of these procedures and that the bulk of the decrement occurred in the first four weeks.

2. Comment

Though the system studied is quite different from an aircraft, the data are consonant with most studies of procedures retention in aircraft skills. The high levels of procedures skill attainable with inexpensive, low-fidelity devices supports the use of such devices in aircraft proficiency maintenance or retraining programs.

44. Hammerton, M. "Retention of Learning in a Difficult Tracking Task." J. Exper. Psychol., 1963, 66, 108-110.

1. Summary

This study investigated retention of skill in a second-order (acceleration control) tracking task. The task consisted of capturing a light spot target presented on a CRT with a joy-stick control and moving it to a center target zone for a specified time. Two levels of initial training were used, and retention over a 26-week interval was investigated. Results showed a five-fold increase in target acquisition time after the retention interval for the lesser trained group and a two-fold increase for the higher trained group.

2. Comment

This study, in contrast to much of the motor skills research literature, shows a significant decrement in performance after six months without practice. The author concludes that use of a higher-order control system, with the consequent increase in task difficulty, accounts for the performance decrement. He also concludes that overlearning should be recommended for difficult tasks when first-trial performance is important, but because of rapid relearning that overlearning need not be used when circumstances will permit refresher training before the criterion task must be performed. This result suggests that for even the more difficult aspects of USAF piloting motor skills, retraining should be rapid.

62. Melton, A.W. Retention of Tracking Skills. Department of Psychology, University of Michigan ORA Project 02855, 1964.

1. Summary

This laboratory study investigated the retention of a tracking skill as a function of type of display-control relationship, type of target motion, and retention interval. The task involved use of a stick to control an oscilloscope target whose motion was either patterned or random. The relationship of stick movement and target motion could either be compatible (i.e., R-R and L-L) or incompatible (R-L and L-R). Retention intervals were 5 minutes, 1 day, and 1 week. Results showed decrements after the 1 day and 1 week interval, with the decrement being more pronounced for the incompatible control-motion relationship.

2. Comment

This effort was the culmination of a series of studies relating to the interference theory of forgetting. The major point of interest with respect to current USAF problems may be the conclusions relating to the effects of control-display compatibility on retention. An interesting sidelight of one of the preliminary studies in this series was the finding that male Ss exhibited superior tracking skill performance compared to that of female Ss, with the difference being quite pronounced for the incompatible control-display condition.

68. Meyers, J.L. "Retention of Balance Coordination Learning as Influenced by Extended Lay-Offs." The Research Quarterly, 1967, 38, 72-78.

1. Summary

Retention of skill in the Bachman ladder climb task by female subjects was examined for five time periods varying from 10 minutes to 13 weeks. Retention was found to be virtually perfect for all five retention periods examined, with no differences among the five groups.

2. Comment

This task has little relevance to flying, other than the fact that it is a complex motor coordination task. It should also be noted that none of the groups had approached asymptotic performance levels prior to the retention interval. However, the results do suggest that retention for some motor skills can remain extremely high over the time periods tested. In a companion article in the same periodical (1968, 39, 314-320), the author reexamined these data to assess effects of retention interval on the correlation of last learning trial with first retention trial. She found that this correlation declined as the retention interval became longer.

75. Noble, M. and Trumbo, D. "The Organization of Skilled Response." Organizational Behavior and Human Performance, 1967, 2, 1-25.

100. Swink, J., Trumbo, D. and Noble, M. "On the Length-Difficulty Relation in Skill Performance." J. Exper. Psychol., 1967, 74, 356-362.

103. Trumbo, D., Noble, M., Cross, K. and Ulrich, L. "Task Predictability in the Organization, Acquisition, and Retention of Tracking Skills." J. Exper. Psychol., 1965, 70, 252-263.

104. Trumbo, D., Noble, M., and Swink, J. "Secondary Task Interference in the Performance of Tracking Tasks." J. Exper. Psychol., 1967, 73, 232-240.

105. Trumbo, D., Ulrich, L., and Noble, M.E. "Verbal Coding and Display Coding in the Acquisition and Retention of Tracking Skill." J. Appl. Psychol., 1965, 49, 368-375.

1. Summary

This series of related studies investigated effects of a variety of variables on retention of a CRT pursuit tracking skill. Factors investigated included training level, task predictability, sequence length, rehearsal, secondary task, and retention interval.

2. Comment

Results of these studies confirm the importance of the factors studied on retention. They are generally consonant with the results of other investigations in task settings more closely approximating those of the USAF pilot.

82. Ryan, E.D. "Retention of Stabilometer Performance Over Extended Periods of Time." The Research Quarterly, 1965, 36, 46-51.

1. Summary

Retention of a gross motor balancing task was examined over three time periods (3, 6, and 12 months). Results showed large performance decrements for all groups, with amount of decrement directly related to length of retention interval. Relearning was rapid, but was slower for the longer retention period groups.

2. Comment

This task has little relevance to flight tasks, but the results are somewhat at variance with other similar studies. Of interest, though, is that correlation of last training trial and first retention trial did not differ as a function of retention interval.

9. Bahrick, H.P. "Retention Curves: Facts or Artifacts?" Psychol. Bull. 1964, 61, 188-194.

This paper examined the question of comparability of retention curves as a function of method of measuring retention (i.e., recognition vs. recall or anticipation methods). The author concludes, contrary to previous investigators, that they are generally comparable. This study, which deals primarily with verbal learning, is of little pertinence to skill retention, but it does point up the bearing that method of measure can have on conclusions drawn from retention data.

22. Brown, D.R., Briggs, G.E., and Naylor, J.C. The Retention of Discrete and Continuous Tasks as a Function of Interim Practice with Modified Task Requirements. Technical Documentary Report, AMRL-TDR-63-35, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1963.

The effect of rehearsal conditions on retention of tracking and procedural skills was examined in this laboratory study. Rehearsal, interpolated mid-way through the 37-day rentention interval, facilitated tracking skill retention over non-rehearsal. Rehearsal also facilitated procedures retention.

28. Duncan, C.P., and Underwood, B.J. "Retention of Transfer in Motor Learning After 24 Hours and After 14 Months." J. Exper. Psychol., 1953, 46, 445-452.

This study examined retention of transfer effects over 1 day and 14 month time periods. Results show proactive inhibition effect in a positive transfer situation over the 14 months period.

58. Leavitt, H.J. and Schlosberg, H. "The Retention of Verbal and Motor Skills." J. Exper. Psychol., 1944, 34, 404-417.

Retention of nonsense syllables and pursuit rotor performance was examined for periods up to 70 days. Results showed better retention of the motor skill.

60. McDonald, R.D. Retention of Military Skills Acquired in Basic Combat Training. HumRRO Technical Report 67-13, Human Resources Research Office, Alexandria, VA, December 1967.

This study examined performance, at several points in time, of Army personnel on (1) basic rifle marksmanship, (2) physical combat proficiency, and (3) an end-of-cycle test covering military subjects taught in basic combat training. Results showed statistically significant decrements in performance as a function of time since training (up to one year). Decrements were of little practical concern, however. This was not a well-controlled study because of prevailing circumstances. Due to this and the nature of the tasks studies, it is of little relevance to flight skill retention.

61. Melnick, M.J., Lersten, K.C., and Lockhart, A.S. "Retention of Fast and Slow Learners Following Overlearning of a Gross Motor Skill." J. Motor Behavior, 1972, 4, 187-193.

Retention of stabilometer balancing skill over a one week period was examined as a function of whether the S was classified as a slow, medium, or fast learner during original training. Each S received 100% overlearning after achieving criterion performance, followed by the one week retention interval. No significant difference in amount retained was found among the groups, though the results did favor the faster learners.

71. Naylor, J.C. and Briggs, G.E. "Effect of Rehearsal of Temporal and Spatial Aspects on Long-Term Retention of a Procedural Skill." J. Appl. Pshchol., 1963, 47, 120-126.

Whole task rehearsal was found superior to other methods for a procedural task, but only for errors of commission.

72. Naylor, J.C., Briggs, G.E., Brown, D.R., and Reed, W.G. The Effect of Rehearsal on the Retention of a Time-Shared Task. Technical Documentary Report No. AMRL-TDR-63-33, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, April 1963.

Whole- and part-task rehearsal conditions were examined in terms of their effects on retention. Results showed whole-task rehearsal to be superior up to five days, part-task rehearsal superior at ten days, and no rehearsal effects were noted when the interval was greater than ten days.

81. Roehrig, W.C. "Psychomotor Tasks with Perfect Recall after 50 Weeks of No Practice." Perceptual and Motor Skills, 1964, 19, 547-550.

Seven subjects were tested for retention of a whole-body balancing skill after a period of 50 weeks without practicing the task. For all subjects, retention was virtually perfect, and their performance during further training after the initial retention trial continued to improve as if there had been no break in their training. The author believes this to be the only documented instance of such complete retention over an extended time interval. He suggests the high motivation level of the subjects (the task had great appeal) as a possible explanation. The task studied here has little resemblance to flying tasks, and this result would seem to have no particular pertinence to flying skill retention.

108. Van Dusen, F., and Schlosberg, H. "Further Study of the Retention of Verbal and Motor Skills." J. Exper. Psychol., 1948, 38, 526-534.

Results of this comparison, involving intervals up to 28 days, indicated no difference in retention of verbal and motor skills when task integration or organization is equal.

109. Vineberg, R. A Study of the Retention of Skills and Knowledge Acquired in Basic Training. HumRRO Technical Report 75-10, Human Resources Research Organization, Alexandria, VA, June 1975.

Retention of material learned during Army basic training was measured six weeks after completion of basic training. Probability of passing dropped from 81% at the end of basic training to 65% six weeks later. Performance of Mental Category II soldiers was significantly better than that of Categories III and IV personnel at both points, but there was no difference in performance of Categories III and IV personnel.

V. MISCELLANEOUS AVIATION STUDIES

In the course of the literature review, many studies dealing with flying skills, learning, flight safety, and aviation in general were examined. No attempt has been made to cover these areas exhaustively, but a number of such items that surfaced in the search procedure are included here as being of some pertinence and interest.

Since the subjects of initial acquisition (learning) of flying skills, maintenance of proficiency, forgetting/retention of flying skills, and reacquisition (retraining) or transfer of flying skills are all closely related, it is obvious that a study dealing with conditions that foster the learning of flight skills may be pertinent to the present problem context of retention. Therefore, certain of these are included in this section. Examples of such topic areas of concern to USAF with reference to the retention problem are use of simulators for cost-effective (re)training, the nature of the pilot task, performance measurement techniques, pilot motivation, accident experience, and the like.

REFERENCES INCLUDED IN SECTION V

Formats A & B

Format C

Format C

5. American Airlines. Optimized Flight Crew Training: A Step Toward Safer Operation. American Airlines Flight Training Academy, Fort Worth, TX, April 1969.

1. Summary

This report describes the effort by American Airlines to develop an improved flight crew training program involving major reliance on the use of flight simulators, training to proficiency, and similar factors that are today routine aspects of airline training. It was not so much a research study, as an advanced development activity involving a variety of training concepts developed elsewhere. The study involved the training of 40 Captains for the B-727 aircraft. Times to reach required proficiency levels varied from 15.2 to 46.7 hours in the simulator (M = 28.4) and from 4.0 to 8.0 hours in the aircraft (M = 5.6). Average times required in the previous B-727 program were 18.0 and 8.3 hours for the simulator and aircraft, respectively. Conclusions included the following:

a. The optimized program will produce safer and better qualified crewmen than conventional training programs.

b. Simulator training to proficiency will assure a high level of success in the airplane.

c. Evaluation in the flight simulator is indicative of performance in the airplane.

2. Comment

This was a pioneering effort which demonstrated the utility of the modern simulator (with a visual system) as a means of meeting virtually all the objectives of airline transition training. Even though most of the training technology involved in this program was developed in military settings, it remained for the commercial carriers to integrate the concepts into an operational program and to demonstrate its cost effectiveness. This program was significant in demonstrating the effectiveness of the approach used in the training of flight personnel of relatively high experience levels. This particular study sheds no light on the subject of long-term retention, but it does suggest ways the retraining can be accomplished in effective and efficient fashion for high level skills.

27. Dougherty, D., Houston, R.C., and Nicklas, D.R. Transfer of Training in Flight Procedures from Selected Ground Training Devices to the Aircraft. NAVTRADEVCEN-TR-71-16-16, U. S. Naval Training Device Center, Port Washington, NY, 1957.

1. Summary

This study examined transfer of flight procedures for several ground training devices varying in fidelity and complexity from a photographic cockpit mockup to an operational flight trainer with visual display. Results showed substantial transfer from all devices to the aircraft for procedural items. Transfer was less for flight control items for all devices, and the mockup device was significantly inferior to the other devices for flight control items.

2. Comment

This is a classic study of device fidelity. While it is not concerned with long-term retention of flight skills, it is pertinent because it demonstrates the feasibility of using devices, including low-cost devices, to maintain or retrain the aspect of flight skill that seems of most concern in terms of long-term retention, the execution of procedures.

29. Fleishman, E.A. and Ornstein, G.N. "An Analysis of Pilot Flying Performance in Terms of Component Abilities." J. Appl. Psychol., 1960, 44, 146-155.

1. Summary

This effort represented the extension to flying skills of a long series of investigations by Fleishman as to the basic structure of motor skills and performance. Objective flight performance data for 63 USAF primary flight trainees were subjected to factor analysis. A total of 24 flight maneuvers were scored over four successive flights. Six factors were identified as underlying these flight performances, as follows: I - Control Precision; II - Spatial Orientation; III - Multilimb Coordination; IV - Response Orientation; V - Rate Control; and VI - Kinesthetic Discrimination.

2. Comment

This study was the pioneering application of factor analysis methodology to the area of flying skills. It laid the foundation for several subsequent investigations by Fleishman and others who have sought to develop a better understanding of the nature of complex skills and performance. While this study does not deal with long-term retention, it does provide a basis for certain positions concerning the nature or structure of what is learned, what is retained, and what is forgotten in the complex area of flying. Research subsequent to this first factorial study of flying skills suggests that this approach may be fundamental to an understanding and effective management of the learning and forgetting of flying skills.

32. Gabriel, R.F., Burrows, A.A., and Abbott, P.E. Using a Generalized Contact Flight Simulator to Improve Visual Time Sharing. NAVTRADEVCEN-TR 1428-1, U. S. Naval Training Device Center, Port Washington, NY, 1965.

1. Summary

This study investigated use of a simple visual device and tachistoscopic speed-reading training as a means of enhancing visual scan and outside-the-cockpit target (intruder) detection of A4 pilots. Effectiveness data were based on performance in a high fidelity operational flight trainer with visual attachment. Results showed the training improved probability and speed of detecting front intruders with no change in flight control performance indices.

2. Comment

The significance of this effort relates to its demonstration of the potential for maintaining or retraining proficiency in visual skills and time sharing through the use of simple training devices. Of interest is the fact that the time between the experimental training and the transfer trials was at minimum one month, and was three months for many subjects. This indicates some retention over time of the skills developed by the special training.

38. Goorney, A.B. The Human Factor in Aircraft Accidents--Investigation of Background Factors of Pilot Error Accidents. FPRC 1227 (Unedited Draft). Aeromedical Training Centre, RAF, North Luffenham (England), undated.

1. Summary

Records from 199 pilot error accidents, covering a two-year period, and from a 165 man control group were examined in this RAF study. Variables analyzed included experience, fatigue, emotional stress, inattention, medical factors, age, and environmental factors. Aircraft types included trainers, fighters, bombers, transports, and helicopters. Results suggest total experience and time in type as the factors most closely related with accident. Age was not found to be a significant factor, nor was period of continuous flying duty (i.e., number of years in cockpit assignments before a ground tour assignment).

2. Comment

These data are not pertinent to USAF long-term retention questions, with possible exception of those dealing with age and ground tour break in flying duties.

47. Haygood, R.C., Leshowitz, B., Parkinson, S.R., and Eddowes, E.E. Visual and Auditory Information Processing Aspects of the Acquisition of Flying Skill. AFHRL TR-74-79, Air Force Human Resources Laboratory, Brooks AFB, TX, December 1974.

59. Leshowitz, B., Parkinson, S.P., and Waag, W.L. Visual and Auditory Information Processing in Flying Skill Acquisition. AFHRL TR-74-103, Air Force Human Resources Laboratory, Brooks AFB, TX, December 1974.

1. Summary

This report describes efforts to develop a better understanding of piloting tasks in terms of information-processing skills. It builds the case around concepts of modern information theory and views the pilot primarily as an executive decision maker whose basic function is the processing of information. This view is contrasted with the more traditional view of pilot skill as a build-up of habits. The authors review information theory in terms of its relationship to flying activities. A series of experiments is described dealing with areas such as visual and auditory interference, digit span, and redundancy. The authors conclude that ". . .tools have been made available with which to probe nonoptimal processing strategies of student pilots and to teach more effective techniques for flying."

2. Comment

While the focus of this effort was on UPT flying tasks and considerable research will be necessary before a usable model is available, this approach would seem of importance to an understanding and effective management of the problems of long-term retention of flying skills. Most retention research, to date, has concentrated on variables more relevant to the "habit build-up" view of flying, and relatively little attention has been given to retention under the information processing model. For example, perhaps the most important matter of concern in selecting individuals for retraining after non-flying periods is whether or not their basic information processing speed and capacity have declined below acceptable levels, if indeed, decline is characteristic of such situations. In any event, the concepts of information processing would seem to offer a worthwhile approach for future USAF examination of long-term retention problems.

50. Hulin, C. L. and Alvares, K.M. An Evaluation of Three Possible Explanations of the Temporal Decay in Predicting Pilot Proficiency. AFHRL-TR-71-5, Air Force Human Resources Laboratory, Brooks AFB, TX, February 1971.

51. Hulin, C.L. and Alvares, K.M. Three Explanations of Temporal Changes in Ability-Skill Relationships: Literature Review and Theoretical Analysis. AFHRL-TR-71-6, Air Force Human Resources Laboratory, Brooks AFB, TX, February 1971.

52. Hulin, C. L. and Alvares, K.M. Effects of the Man on the Task in Complex Man-Machine Systems. AFHRL-TR 71-7, Air Force Human Resources Laboratory, Brooks AFB, TX, February 1971.

1. Description

These three related papers describe the background for and an experimental evaluation of three alternative explanations of the relationships among abilities and skills. The three theoretical positions are: (a) the changing task model;[1/] (b) the changing subject model; [2/] and (c) the changing task, changing subject model. This latter position is propounded for the first time by the authors in these papers and is a combination of the first two positions. The authors review the literature in comprehensive fashion as they develop these alternative theoretical positions. A principal point of their concern relates to the practical problem of attempting to predict performance (skill) from various measures of ability or aptitude, and the fact that the precision of such predictions decreases as the time between predictor measure and performance measure increases.

To test these three hypotheses, two groups of students were administered an extensive battery of 12 ability tests at the beginning and again at the end of a 16-week period. The experimental subjects (N=81) received basic private pilot flight training during the interval, whereas the control subjects (N=74) did not. Inflight checkrides, covering some 20 flight maneuvers, were administered to the experimental group at approximately the 10, 25, and 35 hour levels.

[1/] This model, as exemplified in the work of Fleishman, holds that ability factors are fundamental and constant characteristics of the individual, but the importance of these different abilities in performing a given task (i.e., a skill) changes systematically as a function of level of experience or training on the task.

[2/] The changing subject model, as described by Adams, assumes that the abilities required to perform a given task remain constant, but that training actually changes the strength of the underlying abilities of the individual.

2. Results

a. Two factors were identified as basic to the ability test battery--a spatial-visual orientation factor, and a mechanical aptitude factor.

b. There were significantly greater changes in the ability scores (pretest to posttest) of the experimental group than in the control group.

c. Predictive correlations between pretest ability scores and flight check data declined over the three flight check periods.

d. Postdictive correlations between posttest ability scores and flight check data showed no change over the three flight check periods.

e. The spatial-visual factor correlated best with flight performance at the 25-hour check period.

f. The mechanical aptitude factor correlated best with flight performance at the 10-hour and 25-hour check periods.

3. Conclusions

a. Support is provided in these data for both changes in the subjects and changes in the task. Hence, the authors feel the combination model -- the changing task, changing subject model -- is the most likely explanatory mechanism.

b. The traditional distinction between underlying abilities and operational skills is no longer justified.

c. Selection procedures and attempts to predict performance must take into account the changes in abilities and tasks that occur as a result of training and their interactive effects.

d. Practice on a task may alter deficiencies in underlying abilities that existed prior to such practice.

e. These structural changes may provide a means to alter practice (training) in constructive ways to improve training effectiveness and to cater to individual differences.

4. Comment

The line of thought represented by these three papers is of considerable potential significance to the area of skills retention, though the studies themselves do not touch the subject. Questions arise, for example, such as the following: how permanent (i.e., their retention) are changes in underlying abilities that occur as a function of training; since such changes occur as a function of practice, what changes in abilities occur as a function of non-practice or of other experiences; to what extent are the changes in task structure (i.e., the abilities used to execute a task) idiosyncratic to individuals; do some task structures (assuming idiosyncracy) result in better retention of performatory skills over periods of non-practice; etc. The significance of this work to retention lies in the suggestion that

the performance of complex tasks is dependent on many factors and variables, some, or perhaps all, of which are not fixed in amount or effect. While these efforts were concerned with only the rudiments of initial flight training, extension of this thinking to more complex flight skills would force their examination in ways that perhaps emphasize factors other than the more traditional perceptual-motor views of flying. Little has really been done to explore advanced skills (and their retention) in terms of factors or functions such as information processing, residual attention, decision making, crew and resource management, effects of stress, and the like. The line of research represented in the work of Hulin and Alvares, as well as that of Fleishman, Hempel, Adams, Corballis, and others, offers a means of exploring flight skills learning and retention in ways that may prove much more valuable than those used to date.

56. Koonce, J.M. Effects of Ground-Based Aircraft Simulator Motion Conditions upon Prediction of Pilot Proficiency. Technical Report AFOSR 74-3, Aviation Research Laboratory, University of Illinois, Savoy, IL, April 1974.

1. Summary

This study investigated predictive relationships between various measures of pilot performance in a simulator with pilot performance measures gathered inflight. Three groups of thirty pilots, each with multi-engine and instrument ratings, served as subjects. The principal concern was with the effects of several simulator motion conditions on the prediction of inflight performance. In addition, data are presented relating to the relationships between certain background data and inflight performance. Results showed sustained simulator motion allowed more accurate predictions of inflight performance than did either no-motion or washout-motion conditions. Of the prior flight time variables, only flight time in the past six months showed substantial correlation with flight performance. Correlations were low for total flight time or for various categories of flight time (e.g., total instrument time).

2. Comment

The data from this study do not add much to our knowledge of long-term skill retention. While some of the test subjects had not flown for extended time periods, this was not a variable on which they were selected, and no analyses are given for any subgroups who had not flown for extended periods. A reanalysis of these data along that line would be of interest. The data do suggest several things of some interest relative to retention. The finding that amount of recent flight experience is related to flight performance is not surprising, but the finding that type of recent flight experience showed only low relationship to flight performance might be considered unexpected. Also of interest was the finding of substantial predictive relationships between simulator measures and inflight measures. This lends credence to the use of flight simulators as vehicles for studying retention of flight skill.

69. Miller, R.E., Optimal Assignment of Air Force Pilots. AFHRL TR-73-59. Air Force Human Resources Laboratory, Brooks AFB, TX, February 1974.

1. Description

In response to TAC request, this study sought to develop a technique for optimizing pilot assignment within TAC. One constraint was that the assignment system had to be based on information or data available at the end of UPT. Peer rankings of pilot competence served as the criterion of performance to be optimized. Peer rankings, AFOQT scores, UPT grades, and biographical data were gathered for a sample of 784 TAC pilots in ranks 1st LT through MAJ. Correlational and multiple discriminant analyses of the data were performed for transport, fighter, and reconnaissance pilot subsamples.

2. Results

a. The peer rankings showed internal consistency agreement in 41 of 42 organizations surveyed.

b. Entry level TAC pilots had significantly lower peer rankings than did non-entry level TAC pilots.

c. UPT grades tended to be positively related to peer rankings for the fighter group and negatively related for the other groups.

d. Cross validation multiple correlations of predictors and performance ranged .41 - .54.

e. An efficient discriminant function was developed involving 10 variables (1 AFOQT plus 9 UPT).

f. Comparing actual and optimal assignment for the above average pilots, 64% of the fighter subsample were optimally assigned, 55% of the transport subsample, and only 25% of the recce subsample. Optimal percentages for average and below pilots were 48%, 39%, and 23% for the three subgroups, respectively.

g. The assignment procedure would have allowed optimal assignment of 85% of TAC pilots on the basis of total numbers of fighter, transport, and recce pilot positions in the command.

3. Conclusions

a. Pilots show greater than chance agreement in their peer rankings of pilot competence.

b. Performance of fighter, transport, and recce pilots can be predicted at the end of UPT.

c. Predictors for one pilot specialty tend to be different from those of another.

d. The positive relation of UPT grades to fighter pilot performance and negative to transport and recce pilot performance may reflect a fighter emphasis in UPT.

e. An efficient assignment can be made on the basis of 10 AFOQT and UPT variables.

f. While most above average pilots are optimally assigned, the proportion of all pilots optimally assigned could be increased to as high as 85%.

g. Optimally assigned pilots are better pilots, as measured by peer rankings, than those not optimally assigned.

4. Comment

This study is abstracted at length here because of the potential utility of such a procedure for identifying pilots who are the best candidates for retraining after periods of non-flying. A predictive procedure could be developed to predict level of skill retention after non-flying episodes, though the development of the necessary data would be a formidable task. Similarly, a prediction of quality of post non-flying episode flight performance (which might be different from the level of skill retention prediction just mentioned) could be developed, given the necessary data and assuming that a discriminant relationship exists. While much research would be required to accomplish these ends, an effective such procedure would make for much more effective and efficient management of the rated force resources. The positive findings in Miller's research are encouraging for development of such a procedure.

80. Prather, D.C., "Prompted Mental Practice as a Flight Simulator." J. Appl Psychol., 1973, 57, 353-355.

1. Summary

Thirteen student pilots listened to four 12½ minute tape recordings that prompted their mental practice of landing the T-37 aircraft. Their performance in landing the aircraft was compared with that of 10 control subjects. Subjects had about 20 hours experience in the T-41 aircraft and 4 hours in the T-37 at the time of the study. Results showed the experimental students to perform significantly better ($p<.05$) on both landing technique and procedures.

2. Comment

The concept of mental practice is of some interest in long-term retention. Mental rehearsal or warmup has been shown to aid task performance after periods of no practice in several different flight-relevant situations. The technique could be of some possible use, both in the maintenance of skill levels during periods of little or no flying, and in the retraining of flight skills after extended no flying periods.

118. Zeller, A.F. "Current Flying and Accident Potential." Aerospace Medicine, 1962, 33, 920-929.

1. Summary

Data were gathered concerning current flying, background experience, and age for USAF pilots involved in over 1,000 jet aircraft accidents during the one-year period July 1957-June 1958. Data were compared with those from a 10% sample of all Air Force pilots flying comparable equipment during the same period. Accident rates were highest for those pilots under 25 and over 40 years of age, generally, with pilots in the 30-34 year age group having the lowest rate. Rates were generally higher for those with less total experience or for less experience of a pertinent type (e.g., Century series accident rate as a function of amount of jet experience). In practically all situations examined, those with greater currency (i.e., number of first or instructor pilot hours in six-month period) had lower accident rates. The author notes that there are marked differences in accident rate as a function of aircraft type, age, experience, and other group factors, but that the relationships were in the expected directions with reference to the importance of currency. It is noted that pilots 40 years or older should fly high performance fighters only when necessary and with high currency. However, this admonition does not apply to jet bomber pilots, as their accident rate shows little or no difference from that of younger age groups.

2. Comment

This is an excellent overview of USAF's early experience with higher performance aircraft. While the study does not touch on retention of flight skills, the comments concerning currency, age, and performance are of interest.

120. Zeller, A.F. and Burke, J.M. "Relation of Time Between Flights to the Accident Potential of Century Series Pilots." Aerospace Medicine, 1967, 38, 998-1001.

1. Summary

Time between flights for 204 tactical and interceptor pilots who had accidents during the years 1963-1964 was compared with that of two matched control groups of 204 each who did not have accidents. No differences were found between the accident and control groups. The author suggests that the strongly held belief that time between flights is a strong accident causal factor must be reexamined.

2. Comment

The concern here was with currency of pilots who were flying with some regularity, rather than with long-term retention. Nevertheless, the failure to confirm the commonly held belief concerning time between flights and accidents was a surprise.

4. Adams, J.A., Mengelkoch, R.F., and Gainer, C.A. Survey of Flying Proficiency Problems in the Naval Air Reserve Training Command. NAVTRADEVCEN 71-16-17, U. S. Naval Training Device Center, Port Washington, NY, 1958.

The flying proficiency problems of selected Naval Air Reserve units were examined in this study, and recommendations for improvement were formulated. Results are of little current interest, though reported instances of forgetting and general flight skill deficiencies are probably typical of current programs.

15. Bowen, H.M., Bishop, E.W., Promisel, D., and Robins, J.E. Study, Assessment of Pilot Proficiency. NAVTRADEVCEN 1614-1, U. S. Naval Training Device Center, Port Washington, NY, 1966.

A method of measuring pilot proficiency utilizing the operational flight trainer for the Navy's A4 aircraft is described.

16. Brecke, F.H., Gerlach, V.S., and Shipley, B.D. Effects of Instructional Cues on Complex Skill Learning. AFOSR TR-75-0201, Arizona State University, Tempe, AZ, August 1974.

This study describes the method used to develop effective instructional cues for use in cognitive pretraining. While of no direct relevance to retention, the procedure could be useful as a means of enhancing retraining of flight skills.

18. Briggs, G.E., and Naylor, J.C. "The Relative Efficiency of Several Training Methods as a Function of Transfer Task Complexity." J. Exper. Psychol., 1962, 64, 505-512.

19. Briggs, G.E., and Naylor, J.C. "Team Versus Individual Training, Training Task Fidelity, and Task Organization Effects on Transfer Performance by Three-Man Teams." J. Appl. Psychol., 1965, 49, 387-392.

20. Briggs, G.E., Naylor, J.C., and Fuchs, A.H. Whole Versus Part Training as a Function of Task Dimensions. NAVTRADEVCEN-TR-950-2, U. S. Naval Training Device Center, Port Washington, NY, 1962.

This study examined efficiency of four training methods in the acquisition of training skill and transfer effects for two levels of task complexity. Results are of interest in training, but are not directly pertinent to long-term retention.

21. Briggs, G.E., and Wiener, E.L. "Influence of Time Sharing and Control Loading on Transfer of Training." J. Appl. Psychol., 1966, 50, 201-203.

This study investigated tracking task fidelity (in terms of control loading) and its effect on transfer. While of interest to simulator design and use, this report is not especially relevant to long-term retention.

25. Copp, M.R. Pilot Age and Experience Versus Performance and Proficiency. Operations Analysis Working Paper No. 71-6 (TAC OA WP-71-6). Hq., Tactical Air Command, Langley AFB, VA, June 1971.

The author reviews various safety studies and concludes that age alone is not the critical factor in pilot performance. Age must be considered along with experience, background aircraft type, and mission. The first 4-5 years of flying are the most dangerous for fighter pilots. Jet fighter accident rates are much higher than for non-jet. Age has less effect in prop AC. The writer cites data indicating that age is related to training scores in fighter CCTS. He concludes that USAF should not enroll pilots in fighter CCTS after age 35.

39. Gopher, D. and North, R.A. The Measurement of Operator Capacity by Manipulation of Dual-Task Demands. AFOSR-TR-75-0409. Aviation Research Laboratory, University of Illinois, Savoy, IL, October 1974.

This study investigated a technique for measuring operator task load and attention capacity. Results indicate that the technique may be useful in predicting flight performance. If the long-term skill retention problem is conceived as being, at least in part, one of retention of information processing capability or retention of pilot task attention resources, this technique might be useful in predicting pilot performance or retrainability after extended non-flying episodes.

64. Meyer, R.P., Laveson, J.I., Weissman, N.S., and Eddowes, E.E. Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Executive Summary. AFHRL TR-74-33(I), Air Force Human Resources Laboratory, Brooks AFB, TX, December 1974.

65. Meyer, R.P., Laveson, J.I., Weissman, N.S., and Eddowes, E.E. Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Surface Task Analysis, Taxonomy Structure, Classification Rules and Validation Plan. AFHRL TR-74-33(II), Air Force Human Resources Laboratory, Brooks AFB, TX, July 1974.

66. Meyer, R.P., Laveson, J.I., Weissman, N.S., and Eddowes, E.E. Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Taxonomy Refinement. AFHRL TR-74-33(III), Air Force Human Resources Laboratory, Brooks AFB, TX, December 1974.

67. Meyer, R.P., Laveson, F.I., Weissman, N.S. and Eddowes, E.E. Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Guidelines and Examples for Taxonomy Application in Flying Training Research. AFHRL TR-74-33(IV), Air Force Human Resources Laboratory, Brooks AFB, TX, December 1974.

This series of reports presents a methodology for task analysis and classification of undergraduate flying skills. The methodology is aimed at development of a behavioral taxonomy of such tasks and skills which, it is hopes, will lead to more efficient UPT programs and will provide guiance for behavioral research. While nothing in these reports if of direct pertinence to long-term retention, the methodology might well provide a systematic structure for analyzing retraining requirements in terms of fundamental flying abilities, rather than specific flying maneuvers or missions, and, thus, allow development of more effective and efficient retraining programs.

76. Parker, J.F., and Fleishman, E.A. Prediction of Advanced Levels of Proficiency in a Complex Tracking Task. Report 59-255, Wright Air Development Center, Wright-Patterson AFB, OH, December 1959.

This effort investigated relationships of ability factors and performance of a simulated radar intercept task. While the study is of no direct interest to long-term flight skill retention, the results lend some support to the idea that the factorial structure of perceptual-motor skills changes as a function of proficiency level. Subjects in this study were examined in a later study [1] for retention of skills. That study is pertinent to USAF long-term retention problems.

[1] Fleishman, E.A. and Parker, J.F. "Factors in the Retention and Relearning of Perceptual Motor Skill." J. Exper. Psychol., 1962, 64, 215-226.

78. Payne, R.B., and Hauty, G.T. "Factors Affecting the Endurance of Psychomotor Skill." J. Avn. Medicine, 1955, 26, 382-389.

Procedures for studying work decrement in pilot tasks due to fatigue are described. No information relevant to long-term skill retention is given.

98. Stanley, M.D. A Method for Developing a Criterion for Combat Performance of Naval Aviators. Masters Thesis, Naval Postgraduate School, Monterey, CA, June 1973.

In this report, methods for identifying effective and ineffective combat pilots are discussed. The author suggests ratings in UPT based on 10 factors: (1) Situation Awareness; (2) Procedure Ability; (3) Decision Making Capability; (4) Determination/Fixation; (5) Stress Capacity; (6) Lack of Preparation; (7) Excessive Concern with Self Image; (8) Self Confidence/ Over Confidence; (9) Concern; and (10) Communication.

99. Stewart, W.A. Pilot Management Policy and Pilot Training Rates. R-690-PR. Rand Corp., Santa Monica, CA, March 1971.

This report does not deal with long-term skill retention. It does investigate the effects of various options as to length of initial and subsequent cockpit tours on pilot training rates, cost, and force make-up. Of interest are Stewart's observation that it takes about four years of experience (1,200 hours) after UPT for the pilot to become combat effective and his suggestion that presumed negative results (morale, retention in service, motivation, etc.) of changes in cockpit tour patterns may be a self-fulfilling prophecy that is peculiar to the USAF career system as it is presently structured.

101. Taylor, C.W., Murray, S.L., Ellison, R.L., and Majesty, M.S. Development of Motivation Assessment Techniques for Air Force Officer Training and Education Programs: Motivation for Pilot Training. AFHRL TR-71-21. Air Force Human Resources Laboratory, Brooks AFB, TX, July 1971.

This report describes an effort to develop a means to assess motivation for pilot training that would allow prediction of self-initiated elimination (SIE) in UPT. While it does not deal with long-term retention, the report is of interest because of the potential importance of motivational factors in the management of the rated force with reference to periods of non-flying.

111. Willis, M.P., and Peterson, R.O. Deriving Training Device Implications from Learning Theory Principles, Volume I: Guidelines for Training Device Design, Development and Use. NAVTRADEVCEN 784-1, U. S. Naval Training Device Center, Port Washington, NY, July 1961.

112. Willis, M.P., and Peterson, R.O. Deriving Training Device Implications from Learning Theory Principles, Volume II: Methodology. NAVTRADEVCEN 784-2, U. S. Naval Training Device Center, Port Washington, NY, July 1961.

113. Willis, M.P., Rubin, J.A., and Janesko, J.F. Deriving Training Device Implications from Learning Theory Principles, Volume III: Specific Learning Principles. NAVTRADEVCEN 784-3, U. S. Naval Training Device Center, Port Washington, NY, July 1961.

This early and ambitious attempt to bring learning theory into device design in an effective way has little of pertinence to long-term skill retention. The exposition of the theoretical learning positions of Guthrie, Hull, Tolman, Miller, Harlow, Hebb, Estes, Skinner, and Spence is of some interest because of the effort to apply these theories to the practical problems of device design.

119. Zeller, A.F., Lentz, E.C., and Burke, J.J. "Current Flying, Age, Experience and Non-Jet Accidents." Aerospace Medicine, 1963, 34, 222-225.

USAF experience with reference to non-jet aircraft accidents is reviewed. Results show that, in contrast to jet aircraft, age is not a factor related to frequency of accidents for pilots flying non-jet aircraft.

VI. LITERATURE REVIEWS AND REFERENCES

While concern over long-term retention of flying skills has been given impetus by recent events, such concern is not new. Consequently, several previous reviews of the behavioral science literature relevant to this subject, or to closely related areas, have been sponsored by the military services and NASA. In addition, there are several textbooks that are particularly relevant to the subject of retention of flight skills. These review and reference items have been grouped together in this section of the report.

Obviously, every major textbook on learning, experimental psychology, or general psychology is likely to have sections dealing with memory and forgetting, with motor skills, and similar topics. No attempt is made here to cover such items, since they typically do not treat the topic of long-term retention of complex perceptual-motor skills in detail, and seldom will they contain any significant information that is not in one of the primary sources included in this review.

REFERENCES INCLUDED IN SECTION VI

Formats A & B

1. Adams, J.A. Human Memory. New York: McGraw-Hill, 1967.

1. Summary

This book provides a comprehensive treatment of the subjects of memory and forgetting. It provides a discussion of theories of memory, and most of the significant academic literature is treated in systematic fashion. While most of the book is devoted to verbal behavior -- an emphasis which, as the author notes, characterizes research on learning and retention -- the subject of recall of motor response is treated in detail.

2. Comment

Adams has been one of the most productive workers in the field of human memory over the past quarter century, and this volume summarizes much of his thinking. Unlike many of his academic colleagues, Adams' work has spanned the field from theory to real-world practical application. Much of his earlier research was concerned with pilot skills learning and retention. While this textbook is aimed at the academic audience and contains little data directly applicable to current USAF concerns with long-term pilot skill retention, it is highly recommended to the reader as basic background in the skills retention area.

12. Bilodeau, E.A. (Ed.) Acquisition of Skill. New York and London: Academic Press, 1966.

1. Summary

This is an excellent source book on the general subject of skill acquisition. It is a collection of papers presented by eminent researchers in the field at a 1965 conference on skill acquisition. Topics include the history of skill acquisition research, individual differences, tracking behavior, motor-skills learning, and verbal learning. Of particular interest is Bilodeau's chapter on retention. Other portions of the book of pertinence are Bahrick's comments on methods of measuring retention, Poulton's chapter on tracking behavior, Brigg's comments on Poulton's chapter, and Underwood's chapter dealing with motor skills and verbal learning. 1/

2. Comment

This book presents contributions of 18 of the most productive and best known researchers in the field of skills learning. Both the academic and applied settings are represented by this group, many of whom have conducted significant research for the U. S. Air Force. The authors have integrated their many years of research with the general research experience of others into a most comprehensive and thorough examination of their subjects. This book is excellent background for anyone desiring to dig in depth into the area of acquisition of skill.

1/ References to these sections of the book are given in the basic bibliographic listing in Section III of the present report.

14. Blaiwes, A.S. and Regan, J.J. An Integrated Approach to the Study of Learning, Retention, and Transfer -- A Key Issue in Training Device Research and Development. NAVTRADEVCEN-TR-1H-78, Naval Training Device Center, Orlando, FL, August 1970.

1. Summary

The authors make the point that the topics of learning, retention, and transfer (LR&T) are inextricably bound together, though psychologists have often approached their investigation as if they were separate, independent topics. The closeness of their relationship is of major concern for the designer of real-life training systems, particularly when the design of training devices is involved. With this background, they describe attempts by NAVTRADEVCEN to bring information on LR&T together for the purposes of improving the operational uses made of such information and to guide their program of research. They provide some brief overview observations on the state of knowledge in the LR&T area and a tabular review listing of 181 reference items dealing with LR&T. Each item is classified as to nature of the research, task, transfer relationship, and other independent variables involved.

2. Comment

This item is of some general interest as a kind of overview of the LR&T literature. While it includes a few items of interest in the context of long-term retention of skills, the level of detail or information given is of little use in terms of direct application to USAF problems. Of course, the intent was the presentation of an integrative approach or schema for examining the LR&T literature and for its expansion through future research. It was not intended that the report would present the substantive details of that literature.

34. Gardlin, G.R., and Sitterley, T.E. Degradation of Learned Skills: A Review and Annotated Bibliography. Boeing Document D180-15080-1, The Boeing Company, Seattle, WA, June 1972.

1. Summary

As a result of the variety of extended manned spaceflight missions that were planned by the National Aeronautics and Space Administration (NASA), the Boeing Company undertook a series of studies for NASA concerned with long-term retention of spaceflight skills. One aspect of that effort involved a review of the literature dealing with retention (or its opposite, degradation) of learned skills.

The authors conducted a review of both the general literature dealing with long-term retention and the literature that is more specific to long-term retention of tasks relevant to spaceflight. They present rather detailed summary abstracts for some 21 reports of retention research and shorter summary abstracts for 25 additional reports. In addition, a bibliography of 116 items, including those abstracted, is given.

In this report, the authors present an overview of the literature and discuss certain of its implications for the manned spaceflight program and for future retention research. In reviewing the literature, they dichotomize it, generally, into studies occurring prior to 1960 and those occurring subsequent to that date. In their examination of the early literature they rely principally on the excellent summary provided by Naylor and Briggs [1/] in their 1961 publication. They retain the Naylor and Briggs schema for categorizing the early literature with reference to: (a) task variables; (b) training variables; (c) retention interval variables; and (d) recall variables.

The more recent literature is discussed in some detail, and certain trends in that research (variables studied, methodological problems, etc.) are described. The authors present the results of their review of recent literature organized under four independent variable headings: (a) amount of training; (b) duration of retention interval; (c) task organization; and (d) task environment. The latter category includes equipment characteristics.

The authors state that level of performance at the end of training (or immediately prior to the retention interval) is the primary predictor of skill retention for any given retention interval. They emphasize the importance of temporal skills by noting that some literature supports the contention that such skills are the last to be acquired in training and the first to be lost during no-practice intervals. The lack of research dealing with the possible interactions of environmental and psychological

1/ Naylor, J.D., and Briggs, G.E. Long-Term Retention of Learned Skills: A Review of the Literature. ASD-TR-61-390, Air Force Systems Command, Wright-Patterson AFB, OH, August 1961.

stress with retention is noted, as are difficulties in real-world utilization of retention research data due to the contrived or artificial tasks used in so much of the retention research. The needs for better measurement methodologies for retention studies and for a better understanding of the relationship between task elements or dimensions and actual, operational, mission-oriented tasks or behaviors are also highlighted.

2. Comment

This is an excellent and comprehensive survey of the retention literature. It is oriented toward the practical problems of the manned spaceflight program, rather than any specific theoretical position, but the coverage of the general literature does not reflect undue bias. While the review does not provide direct guidance relative to current USAF proficiency retention problems, it does provide an excellent roadmap to primary sources of interest.

35. Ginsberg, R., McCullers, J.C., Merryman, J., Tomson, C.W. and Whitte, R.S., A Review of Efforts to Organize Information about Human Learning, Transfer and Retention. Technical Report No. AMRL-TR-66-23, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, March 1966.

1. Summary

The efforts of some 14 investigators to organize information on learning, transfer, and retention are evaluated. The authors conclude such efforts to develop a comprehensive taxonomy are in only preliminary stages and, consequently, not of general use.

2. Comment

This report provides a quick overview of the positions of the investigators covered. However, its utility for the purpose of the present report is quite limited. Retention receives very little attention, and the treatment of the various positions is quite brief.

70. Naylor, J.C., and Briggs, G.E. Long-Term Retention of Learned Skills: A Review of the Literature. ASD Technical Report 61-390, Air Force Systems Command, Wright-Patterson AFB, Ohio, August 1961.

1. Summary

The Air Force has had a general interest in long-term retention of skills for many years, but as manned spaceflight began to move from the realm of fantasy to fact in the early 1960s, that interest increased. As part of the Air Force investigation of techniques to sustain and/or promote the retention of learned skills over relatively long periods of time without direct task performance, Naylor and Briggs undertook a systematic review of the retention literature.

In their review, Naylor and Briggs cover some 123 items, all but six of which are taken from professional journals or textbooks. While some of the journal articles are based on work that was conducted in something of an applied setting (as in the USAF Behavioral Sciences Laboratory), the great bulk of this literature was based on research conducted in various university laboratories and tends to reflect concern for theoretical considerations. The spurt of recent interest in the subject of retention is reflected in the fact that almost half of the items reviewed by Naylor and Briggs were published in the 1950s. Interestingly, the only 1960 item they cover is the study of the forgetting of instrument flight skills by Mengelkoch et al [1] that remains today as one of the most significant studies of flight skill retention.

In describing the early work on retention, the authors note that it suffers (in terms of the practical problem context of flight skills) from an emphasis on verbal learning retention, as opposed to perceptual-motor skills retention, and from dealing with retention intervals much shorter than those of interest to USAF.

The authors discuss the retention literature in terms of four categories: (a) task; (b) original learning conditions; (c) retention conditions; and (d) recall conditions. Their general conclusions in each of these areas are quoted as follows:

Retention as a Function of the Task

"1. There appears to be little or no evidence to support the hypothesis that motor tasks are intrinsically less susceptible to forgetting than are verbal tasks.

2. While research has indicated differential retention for continuous versus discrete or procedural tasks (in favor of the continuous task), this does not support the above hypothesis that motor tasks are retained better than verbal tasks.

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[1] Mengelkoch, R.F., Adams, J.A. and Gainer, C.A. The Forgetting of Instrument Flying Skills as a Function of the Level of Initial Proficiency. Technical Report NAVTRADEVCEN 71-16-18, U. S. Naval Training Device Center, Port Washington, New York, 1960.

3. Retention differences between motor (continuous) and verbal (procedural or discrete) tasks may be a function of "task integration" or the meaningful patterning of responses. To the extent that a task is composed of responses in random order or without some degree of logical sequential patterning, to that extent the task may involve rapid forgetting following training."

Retention as a Function of Original Learning Conditions

"1. Retention appears to be related in a positive but negatively accelerated fashion to amount of original learning for both simple and complex tasks.

2. In spite of the fact that distributed practice leads to faster acquisition, it does not appear to facilitate retention.

3. Whole learning may lead to better retention, especially for more complex tasks.

4. Verbal practice of a motor skill during acquisition results in better retention than no practice, but in poorer retention than actual task practice.

5. When the retention task is completely specified, specific training is superior to varied task training; however, when the retention task has some degree of uncertainty, varied training is superior to specific training, especially as the amount of such training is increased.

6. Motivational factors during learning may reflect themselves in retention, at least on the more simple motor tasks.

7. Underwood's (1949) hypothesis that most conditions which lead to more rapid learning result in better retention does not seem substantiated in the area of motor skills.

8. The effects of hypnosis on retention appear to be positive and this suggests the utility of such a technique for the training and retention of at least simple procedural skills. The danger here, however, is that it is not possible to anticipate the exact conditions under which operational use of previously learned habits may occur. Thus, a "built in" automaticity of response could prove disastrous under conditions similar to but requiring responses differing from those in the original training."

Retention as a Function of Conditions During Retention Period

"1. Large losses in skill occur over time; however, the actual function of the decrement appears to be specific to the particular situational parameters.

2. Rehearsal facilitates skill retention, and the greater the degree of overt activity in rehearsal, the greater the facilitation.

3. The poorer the fidelity of the rehearsal task to the originally learned task, the less beneficial is rehearsal."

Retention as a Function of Recall Conditions

"1. The choice of a particular retention measure can affect the degree of retention exhibited. For this reason, it is suggested that the criterion for evaluating retention in an experiment should always be the one that is important in the operational task.

2. Retention of skill is directly related to the degree to which the retention environment is replicated during original learning.

3. Warm-up activity prior to retest facilitates the retention process.

4. Hypnosis facilitates recall, especially when the original learning occurred under hypnosis. It is proposed here that the facilitating effect of hypnosis during recall is due to the fact that extraneous stimuli and competing response tendencies are minimized under hypnosis which is, after all, a condition under which the subject's attention is narrowed to a few specific stimuli."

While the authors do not attempt to draw any over-all conclusions from the literature, they do note that the importance of "task organization" as a factor in retention is great and that it is an area in need of more attention. This factor, they feel, may account for the generally popular conception (or misconception) that control skills are better retained than procedural skills. They touch on needs for further research in a variety of areas, particularly methods of measuring retention.

2. Comment

This review provides an excellent overview of the more classical literature on long-term skills retention up to 1960. It is presented in standard review format and provides intergrative commentary pertinent to a theoretical understanding of forgetting. It is a valuable background document for a general understanding of retention, but its direct application to current USAF concern over flying skill retention is limited.

91. Smith, J.F., and Matheny, W.G. Continuation Versus Recurrent Pilot Training. AFHRL-TR-76-4, Air Force Human Resources Laboratory, Brooks AFB, TX, May 1976.

1. Summary

In response to current USAF concern over continuation (i.e., proficiency) training programs, the availability of resources to support such programs, and the readiness of the rated supplement force, the Human Resources Laboratory conducted a survey of the literature on pilot skill retention and developed pertinent conclusions from that literature.

Some 15 references are reviewed briefly in the report. In addition, six bibliographic items are listed, though these are not reviewed. Of considerable interest is the authors' inclusion of data and discussion of unpublished material [1] dealing with the retraining of returned USAF POWs from Southeast Asia. These POW returnees had from 300 to over 7,000 hours of total flight time before being shot down, and time as POW varied from 13 to 102 months. These pilots were retrained by the Air Force in a highly individualized training effort to bring these pilots back up to required proficiency levels. All training took place at a single location.

Due to the period of cessation of bombing of North Vietnam during the conflict, two distinct groups of POWs resulted. Data are presented for two groups: (1) those whose non-flying episode ranged from 13 to 34 months (M = 19 months); and (2) those whose non-flying period ranged from 69 to 102 months (M = 84 months). Retraining flight time for the 21 pilots included in the shorter episode group averaged 38.4 hours, while average time for the 39 pilots in the longer episode group averaged 45.4 hours. Average retraining time for all returnees was 42.2 hours. Grouping the pilots into three categories on the basis of total flight time (Low = 300 - 1,000 hours; Mid = 1,001 - 2,000 hrs.; and High = 2,001 - 7,250 hrs.) resulted in statistically significant differences in retraining time between the low-time group and the other two groups. Mean retraining flight hours were 48.5, 35.3, and 41.6 for the Low, Mid, and High groups, respectively.

[1] No formal publication dealing specifically with POW pilot retraining is known to the present author. However, another exposition based on the POW retraining data, one somewhat more extensive than that of Smith and Matheny, is contained in: Armstrong, M.B., Bleymaier, J.S., Hinkel, J.F., Levins, R., and Sheppard, R.R. Flying Skill Retention and Proficiency Flying. Research Study Report No. 0095-75, Air Command and Staff College, Air University, Maxwell AFB, AL, May 1975.

Based on the studies reviewed and the POW retraining data, the authors identify the following as significant findings:

(a) Motor skills associated with VFR flight are retained longer and regained much more quickly than instrument or procedural and verbal skills.

(b) Inactivity for one year results in near maximum loss of skills (one estimate is 90 percent), and subsequent periods of inactivity add little to average upgrade time requirements.

(c) If instrument flight skills are maintained at a high level, contact flight skills tend to remain at an acceptable level.

(d) Overlearning promoted improved retention of all categories of skills.

(e) Simulators are effective in either learning or relearning procedural and verbal tasks and instrument flying skills, and their use should significantly reduce the hours noted in paragraph (f), following.

(f) Retraining of contact and instrument aircraft flight skills after extended periods of inactivity (13 to 102 months) can be completed in an average of 45 aircraft hours or less per student.

(g) Pilots of low experience levels (less than 1,000 hours) will require more hours to become recurrent, but the overall average should remain below 50 hours per pilot.

Based on these findings the authors conclude that abolition of continuation training could result in significant cost savings to USAF, and that recurrent training could be delayed almost indefinitely until required by new job assignment or other USAF needs.

2. Comment

While the authors describe their review as of limited nature, they have touched on the more significant available documents. The provision of the POW retraining data is a valuable addition to the literature. The depth with which the various studies are reviewed in the Smith-Matheny report is minimal (i.e., the amount of detail in their written discussion), but their conclusions seem well-warranted by the present author's review of the literature. However, as Smith and Matheny note, available data are meager, and more data are needed to permit informed USAF policy.

93. Smode, A.F., Beam, J.C., and Dunlap, J.W. Motor Habit Interference: A Resume of the Literature and the Development of Principles for its Minimization in Training. Contract No. 2515(00), Dunlap and Associates, Inc., Darien, CT, January 1959.

1. Summary

This report examines the concept of habit interference as it applies to motor performance, particularly with reference to the performance of military jobs. The first section presents a rather comprehensive review (148 references) of the technical literature on habit interference. The second section presents certain principles of learning pertinent to minimizing effects of habit interference in training activities. These principles relate to factors such as overlearning, meaningfulness of material, transfer of general principles, perceptual relations, guidance, learning to learn, practice schedules, and procedural variables. The third section deals with the development of more specific principles and hypotheses for minimizing habit interference as a function of the type of behavior of concern. These are classified with reference to whether they operate through training, equipment design, job aids, or personnel selection.

2. Comment

While this report does not deal directly with the subject of long-term retention of skills, it is obvious that the concept of habit interference is crucial to long-term retention. It is generally held that forgetting occurs because of the processes and activities that intervene between learning and performance at some subsequent time; forgetting is not a "decay" process that occurs simply as a result of the passage of time. The provision of specific operational guidelines for minimizing habit interference by Smode et al should be of direct interest to USAF in any future programs of either non-flying or proficiency flying for personnel in the rated supplement. This report is an excellent summary of a considerable body of literature and is recommended to the reader as background for the understanding or the management of the forgetting/retention process.

94. Smode, A.F., Hall, E.K., and Meyer, D.E. An Assessment of Research Relevant to Pilot Training. AMRL-TR-66-196, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, November 1966.

1. Summary

In this exceedingly ambitious work the authors sought to provide the Air Force a state-of-the-art survey of research pertinent to aviation training and to identify researchable issues for improving pilot training. Major sections of the report deal with studies defining the pilot's job, research relevant to pilot training, and studies concerned with improving the training system. They literally cover the subject "from A to Z," utilizing some 336 references ranging from "Abma" to "Zeller." The coverage is very thorough, and the literature is related to major operational and research topical issues in illuminating and competent fashion.

In the section of the report concerned with research studies on pilot training, the authors devote some attention to the topic, "retention of flying skills." Their statements indicate that sensitivity of USAF and the research community to the significant issues in the flight skill retention area has existed for over a decade. The current state of affairs at the time of the present review (1976) indicates that relatively little has been done to advance our knowledge since the Smode et al review.

In identifying the significant research issues in this area, the authors, in addition to studies of forgetting per se, identify task coherency or integration and measurement as two significant aspects of flight skill retention in need of research. Because of the importance of this report and its pertinence to current concerns, the following statements are quoted (p. 175-176) from Smode et al:

> "Research on retention, as presently conceived, has reached an impasse. The same conclusions continue to be generated with very little additional substance added. Entirely new strategies for research are required, set in more operational situations involving complex behaviors defining pilot performance. The obvious start is with programmatic research which systematically investigates the complex of variables subsumed under retention and utilizes various and lengthy time periods between learning and recall.
>
> ". . . An understanding is needed of how behaviors are forgotten in complex tasks, and how the forgetting of constituent components or elements of behavior is related to the total or gross activity. A desired output would be the determination of differential deterioration rates for the classes of tasks found in the pilot's job. . . . Information on the onset of decrement and the shape of the curve of forgetting over time for each task class should be an eventual goal of this research for pilot training. Retention studies over long periods of time are implied, since the effects of long-term retention of skills is so important in aviation."

2. Comment

This report is the best and most comprehensive source document on aviation behavioral research available. The authors touched the significant centers of pilot training research, and their literature coverage is exhaustive, though they focused in large part on the literature published 1960 and later. While the scope of this report is much broader than current USAF concern with long-term retention of flight skills, it is highly recommended as a basic source document for those interested in virtually any aspect of the pilot training process.

95. Smode, A.F., and Meyer, D.E. Research Data and Information Relevant to Pilot Training: I. General Features of Air Force Pilot Training and Some Research Issues. AMRL-TR-66-99(I), Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, July 1966.

96. Smode, A.F., Post, T.J., and Meyer, D.E. Research Data and Information Relevant to Pilot Training: II. Description of Pilot Job Requirements and Training Practices for Representative Missions and Associated Aircraft. AMRL-TR-66-99(II), Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, July 1966.

1. Summary

These two volumes present results of an examination of pilot task and training requirements for aircraft-mission combinations representative of all major USAF combat flying commands (SAC, TAC, MAC, and ADC). Volume I describes general features of USAF pilot training at UPT and CCTS levels and presents a number of "researchable issues for improving aspects of pilot training." Among the issues identified are the following: needs of the CCTS program; training in target recognition and geographic orientation for low altitude flight; definition of the pilot's job; the learning environment; simulation; measurement; future training requirements; field feedback; attitudes and motivation; instructor effectiveness; and training materials guidelines. Of most interest in the present context was the identification of "maintenance of performance" as a research issue.

In describing research needed in this latter area, the authors state (Volume I, p. 34):

> "Research is recommended to determine the quantitative and qualitative effects of disuse on performance and the pilot's ability to retain what he has learned. It is also likely that different types of skills are differentially affected by disuse . . . The recommended study should provide data on the loss of ability through disuse and on differential performance decrements as a function of level of learning (i.e., flying experience). . . . The results of this inquiry would aid in the development of a basic, or core, refresher training exercise which could be used to offset the deleterious effects of disuse. The desired end product is best described as a technique for "peaking" the pilot, i.e., for enabling him to maintain a given skill level through a period of minimal flying time."

The second volume is a detailed examination of the selected aircraft missions and of the various CCTS training programs that support those missions.

2. Comment

While these reports do not contain specific information on flight skill retention, they are cited because of their identification of the research

needs in the retention area. The importance of the retention/forgetting problem has been recognized by behavioral scientists for many years, and these reports are an example of such recognition with reference specifically to USAF combat crew performance.

115. Wright, R.H. Review of Behavioral Science Research Data Relevant to Army Proficiency Flying Programs. HumRRO Consulting Report, HumRRO Division No. 6 (Aviation), Fort Rucker, AL, April 1969.

1. Summary

The report was prepared for the U. S. Continental Army Command (CONARC), now TRADOC, and provided the background for Wright's [1] later study of retention of flying skills by Army pilots. The author examined both specific studies of flying skills (primarily simulator studies) and laboratory studies, as well as general review items. Other research agencies were contacted, and a limited opinion survey was conducted among Army aviators concerning retraining requirements and effects on career decision plans of restricted opportunity to fly.

A bibliography of 76 items is provided in this review, and summary comments on the overall literature are provided. Detailed review and commentary are provided for six simulator studies of flight skill retention, and short comments are provided for four laboratory studies. The author's general interpretive conclusions from the literature survey are discussed relative to the topics of retention and transfer. Conclusions relative to retention were as follows:

(a) Psychomotor skills, such as controlling an aircraft, deteriorate relatively little over periods of up to two years, and relearning to original performance levels should occur within, at most, a few hours.

(b) Procedural skills that lack inherent logical organization are forgotten rapidly, but regaining proficiency requires less practice than original learning.

(c) Degree of original learning and practice is correlated with degree of retention after an interval.

(d) Forgetting curves have a negatively accelerated form, with greatest loss immediately after cessation of practice.

(e) Degree of retention of a task appears to be directly related to its inherent organization. Tasks with a random structure are forgotten rapidly; tasks with high inherent organization are well retained.

(f) Mental (imaginary) rehearsal, although not as effective as actual task practice, facilitates retention.

(g) The degree of overt activity in rehearsal is positively related to degree of recall.

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[1] Wright, R.H. Retention of Flying Skills and Refresher Training Requirements: Effects of Nonflying and Proficiency Flying. HumRRO Technical Report 73-32, Human Resources Research Organization, Alexandria, VA, December 1973.

(h) Initial retention task performance is directly related to the degree to which the retention task duplicates the original learning task.

(i) Initial retention task performance is directly related to the degree to which the interpolated period tasks duplicate the retention task.

(j) Time sharing (i.e., the integration of procedural and flight control activities) appears subject to the rules of forgetting, and some whole-task training appears necessary to restore full proficiency in time-shared activities.

After presenting these general conclusions from the literature review, the author derives certain implications for Army proficiency training policy. Generally, these implications suggest no serious retraining problems would result from non-flying periods up to three years in length. These implications are then discussed as they relate to accident rates, costs, retraining time, habit interference, and effects of non-flying on pilot career plans (i.e., retention in the service). With reference to this latter point, results of the limited opinion survey suggest no significant problem. However, the survey was much too limited in number of respondents to draw any conclusion on this point.

2. Comment

This survey was performed in response to an Army request for information on a fairly tight time schedule. It was somewhat limited in scope for this reason, and, as a quick response to a military requesting agency, the report has not been available as a formal publication. Nevertheless, the summary is reasonably comprehensive, and the author's interpretations are sound.

VII. ITEMS REVIEWED, BUT NOT PERTINENT

A number of items turned up in the literature search that, upon review, were judged to be of no real pertinence to the topic of long-term retention of flying skills. While many such items could be summarily dismissed as of no concern from their titles, abstracts, or other sources, a number could not. Therefore, a number of documents were secured and reviewed in some detail before being rejected from inclusion. This section lists a number of these "reviewed, not pertinent" items. The purpose of this listing is two-fold: (1) to let the reader know that these items were considered, and (2) possibly to save a reader interested in long-term flying skill retention the trouble of examining these items in the future. As can be seen, many of these items have seemingly pertinent titles, but were judged to be irrelevant or to add no worthwhile information concerning our topic of interest. In a broader sense, of course, one can consider even most of these items as of some pertinence, because they do deal with learning or aviation topics.

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